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G1G GRA

(56) Documents Cited
DE 003027923 A1

(58) Field of Search
UK CL (Edition T) G1G GRA
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Other: Online WPI, EPODOC, JAPIO

(54) Abstract Title
Using vibrations generated by movement along a surface to determine position

(57) An input apparatus 102 for a processing system such as a touch tablet having a surface that generates noise during the continuous movement of a fingertip against that surface. The noise is conducted from its origin to transducer means 301 via a system of paths, including a direct path 1011 and reflection paths 1012, 1015, 1018 The transducer 301 is located asymmetrically, so that reflection artefacts uniquely characterise the location 1001 of a sound. Signals from the transducer are transformed 1902, 1908, to reveal reflection artefacts, and a location is identified by processing the transformed data 2301 with a reflection model 906 of the surface.

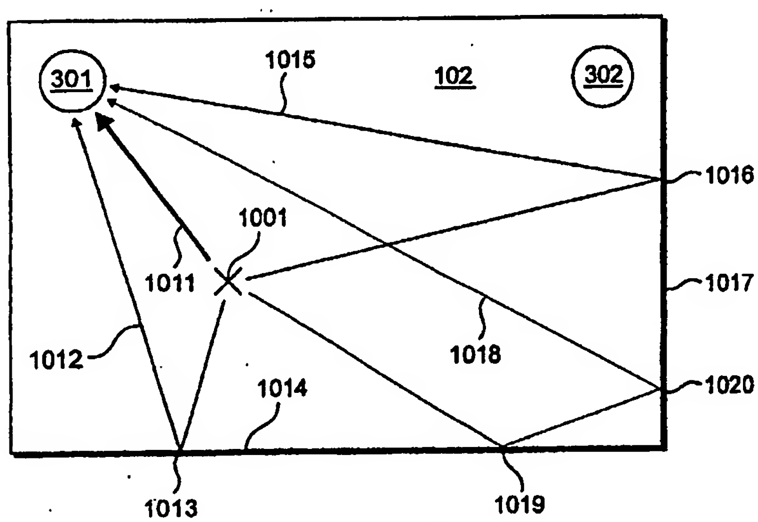

Figure 10

GB 2 385 125 A

C00021437

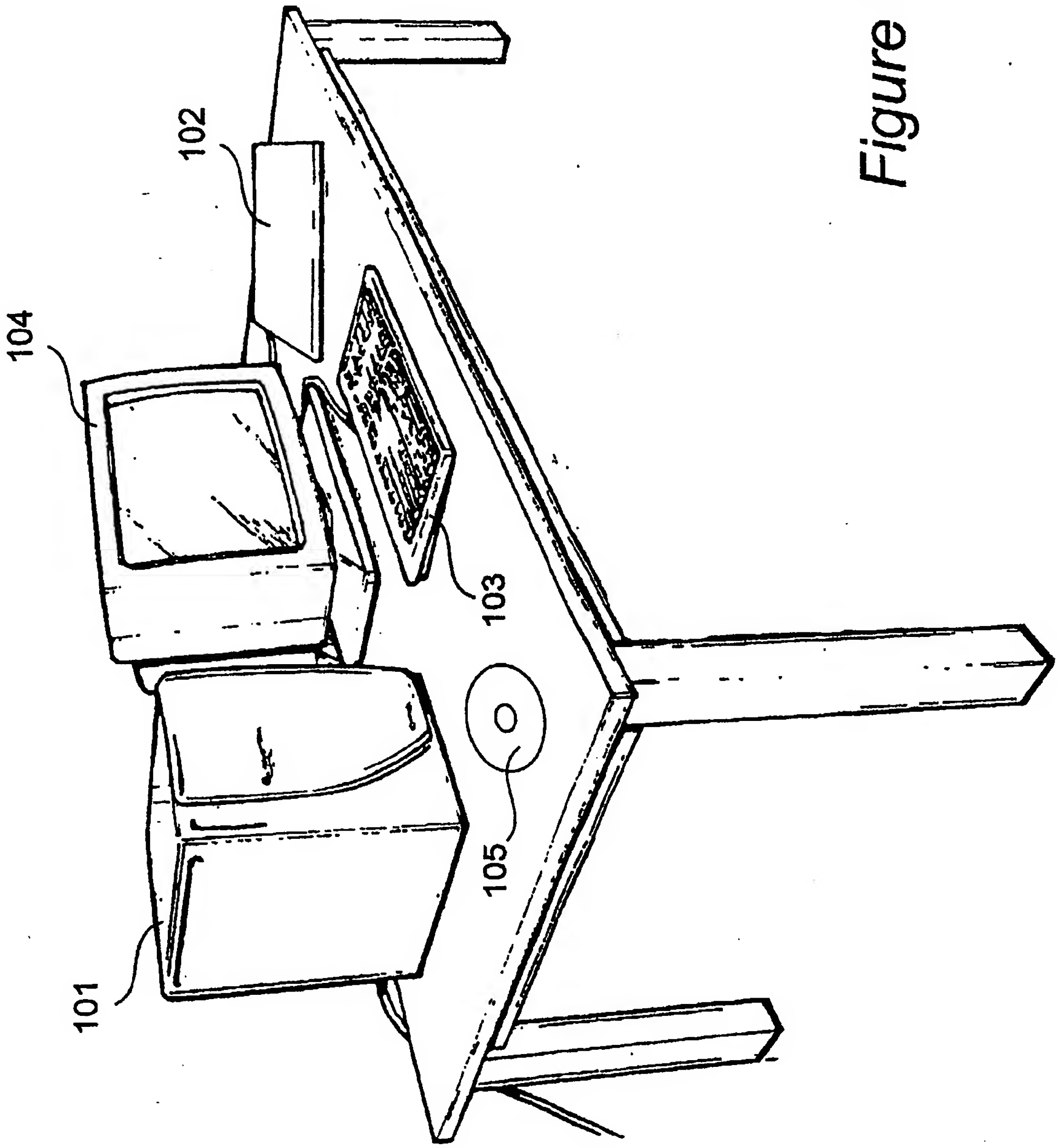

Figure 1

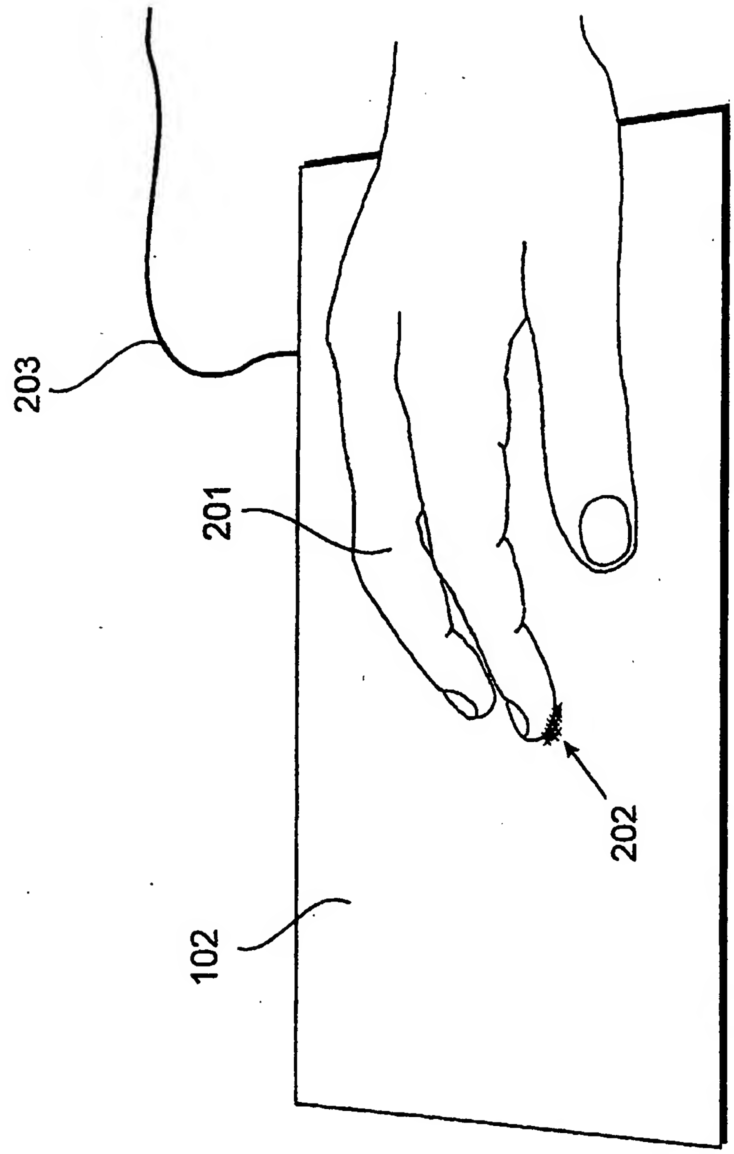

Figure 2

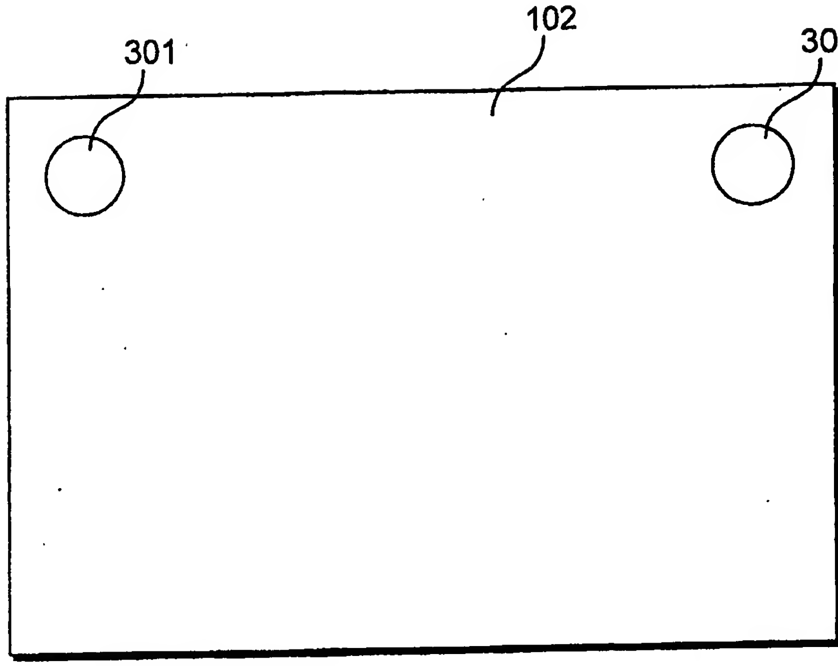

Figure 3

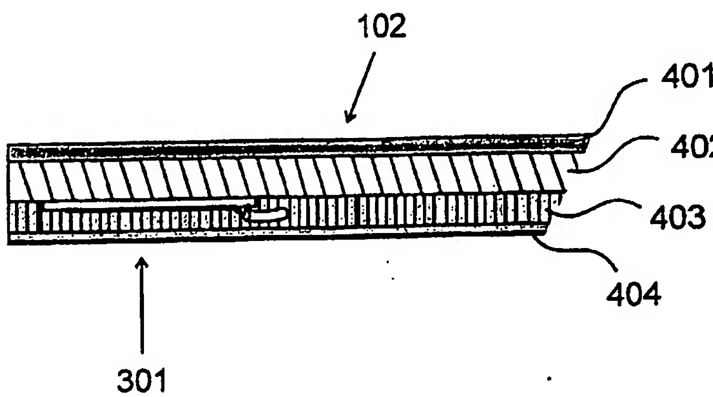

Figure 4

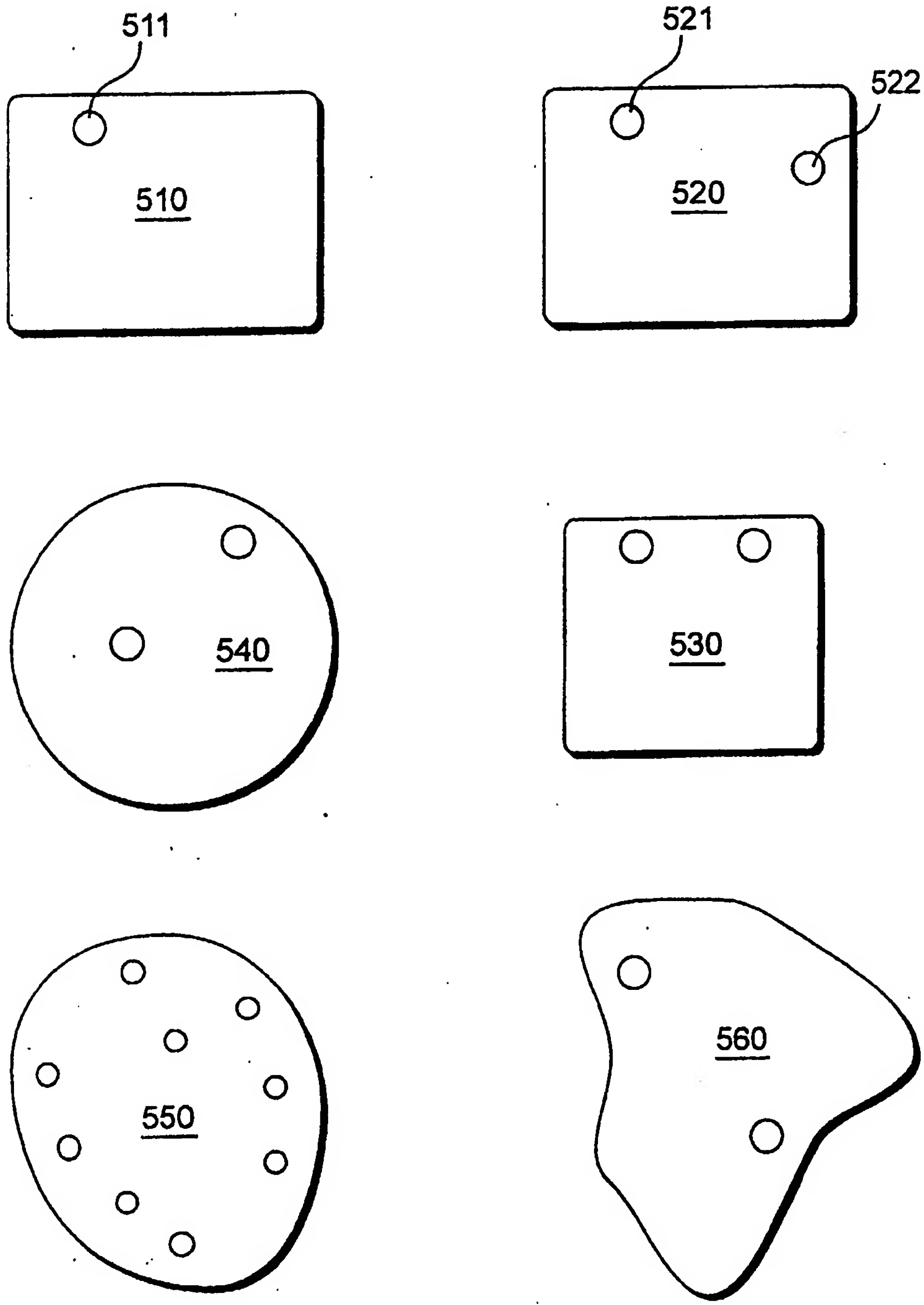

Figure 5

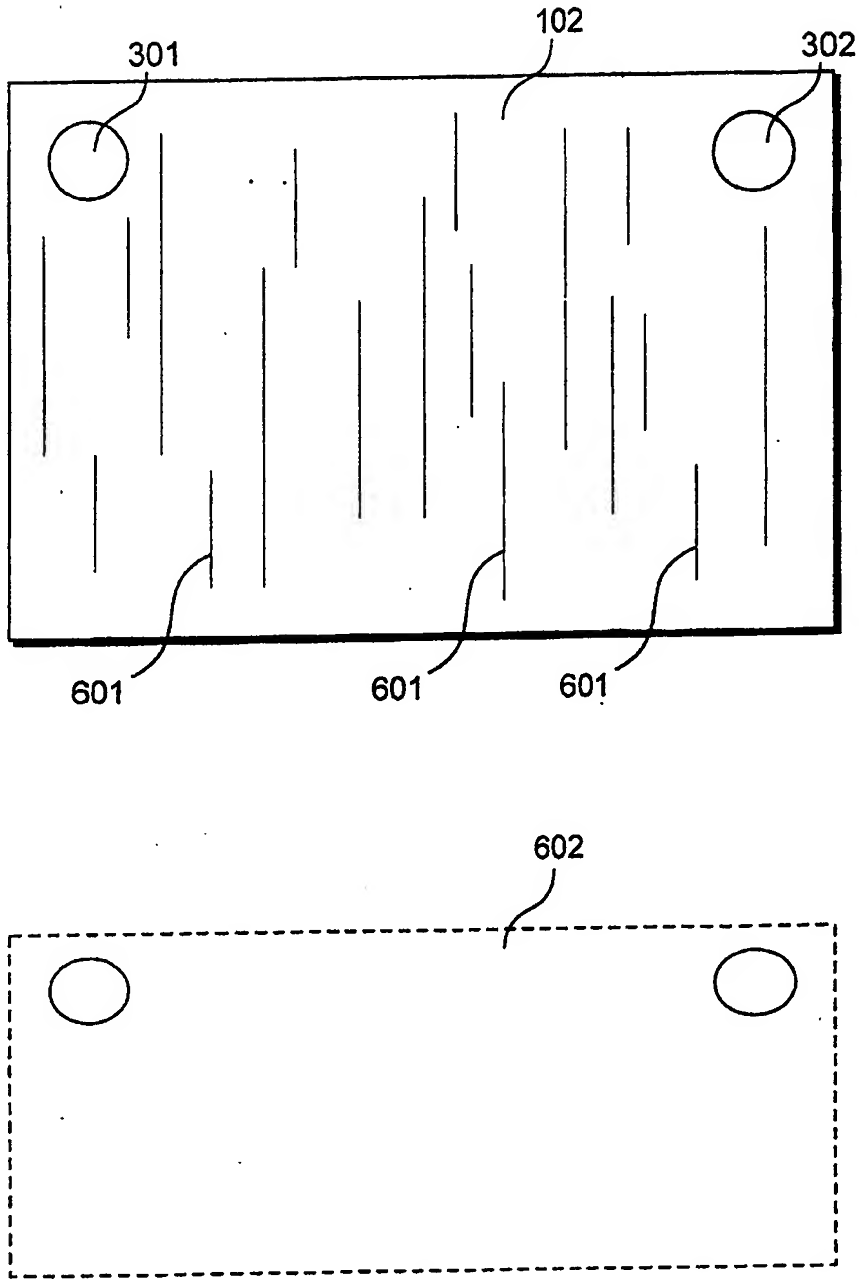

Figure 6

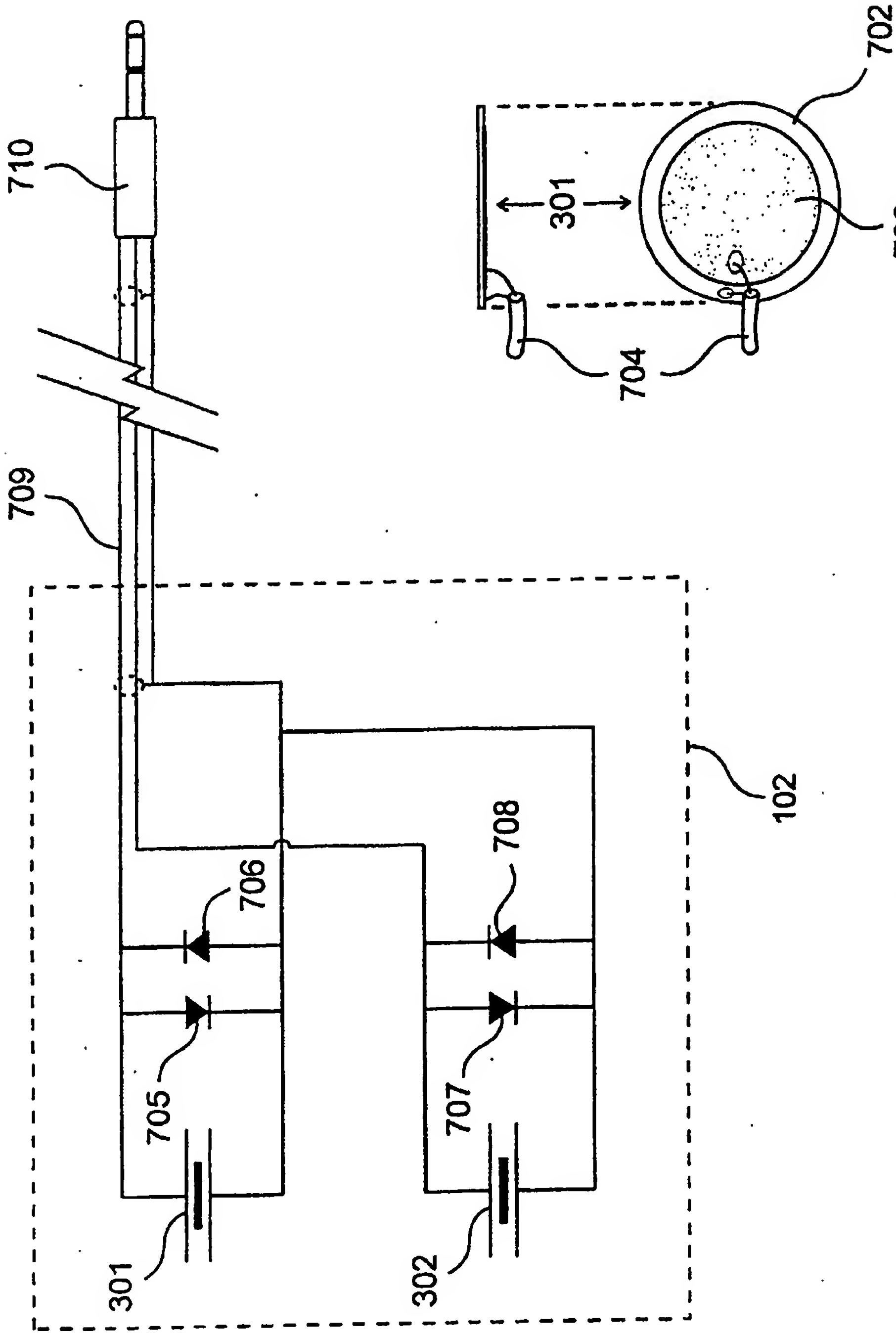

Figure 7

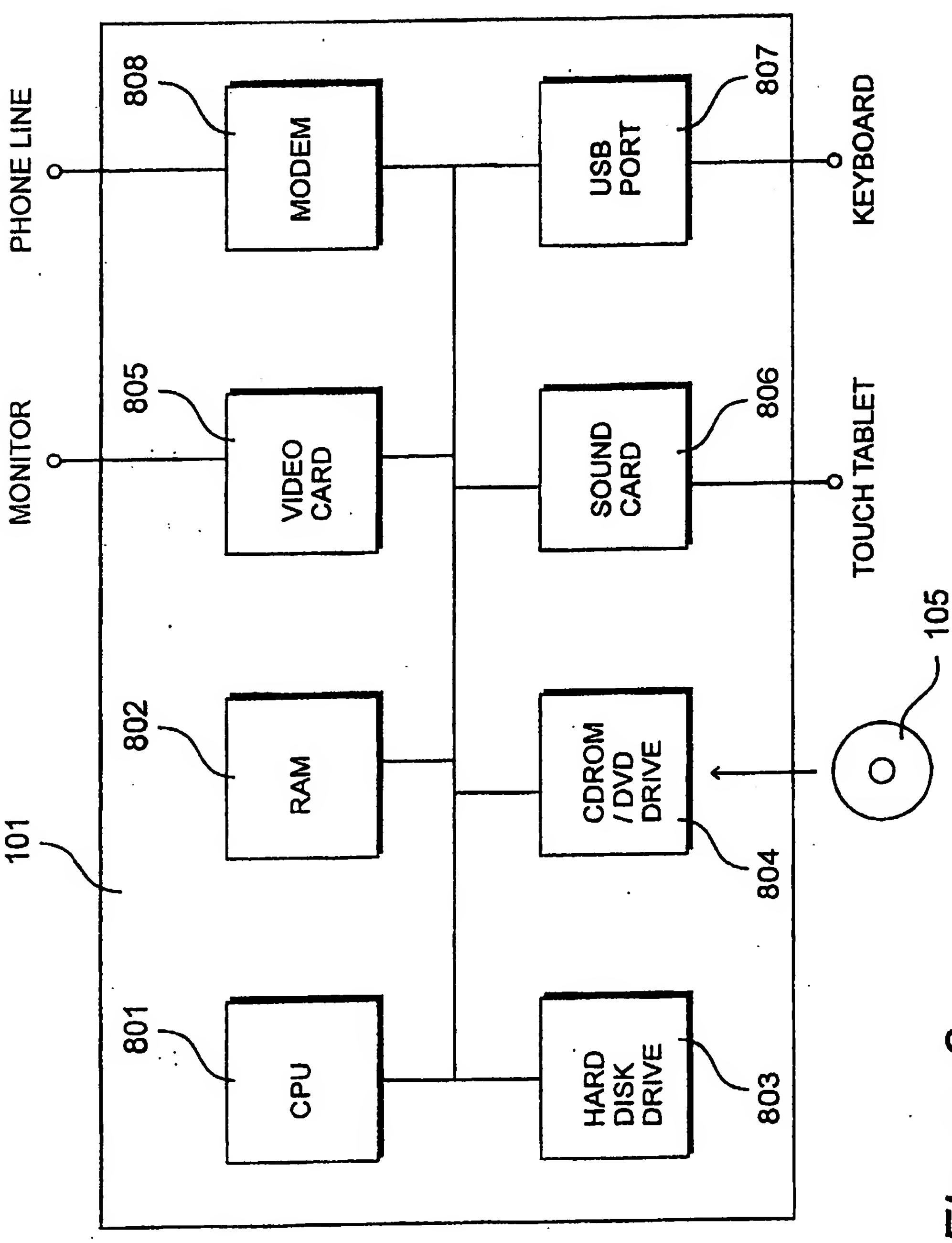
PHONE LINE
MONITOR
101
808
805
802
801
MODEM
VIDEO CARD
RAM
CPU
USB PORT
SOUND CARD
CDROM / DVD DRIVE
HARD DISK DRIVE
807
806
804
803
KEYBOARD
TOUCH TABLET
105

Figure 8

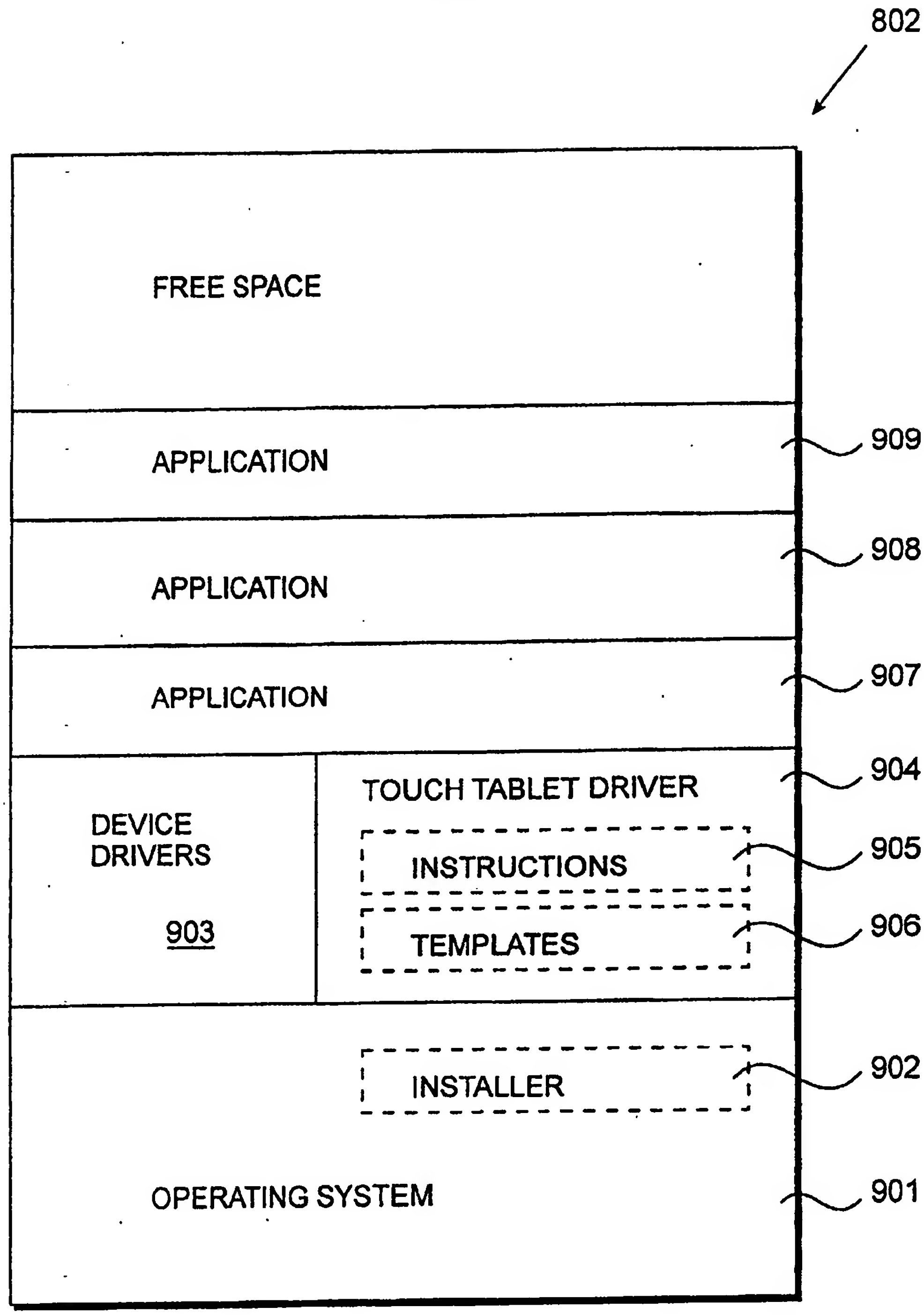
802
FREE SPACE
APPLICATION
909
APPLICATION
908
APPLICATION
907
DEVICE DRIVERS
903
TOUCH TABLET DRIVER
904
INSTRUCTIONS
905
TEMPLATES
906
INSTALLER
902
OPERATING SYSTEM
901

Figure 9

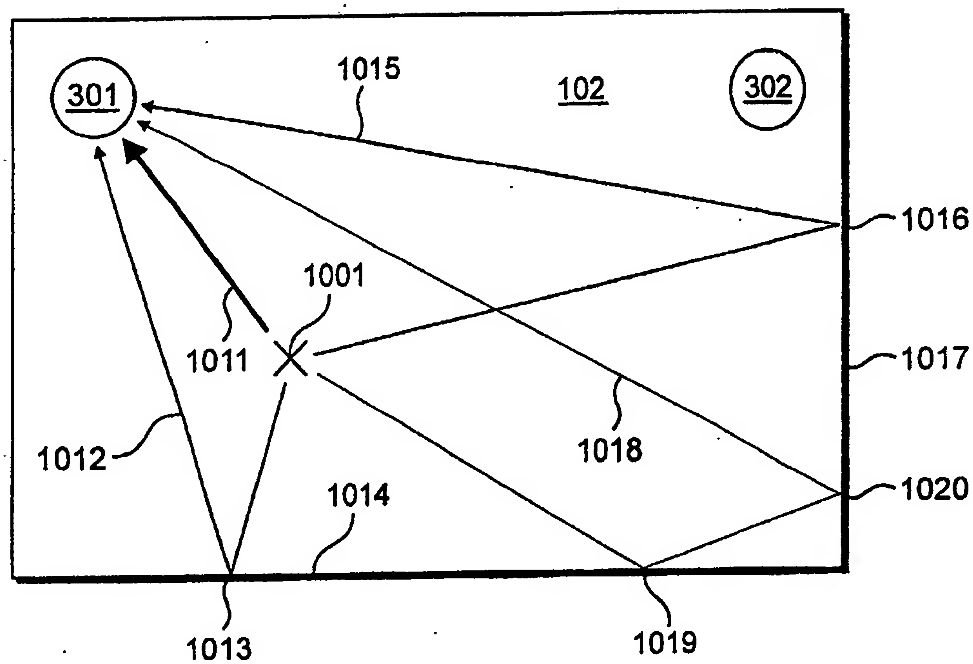

Figure 10

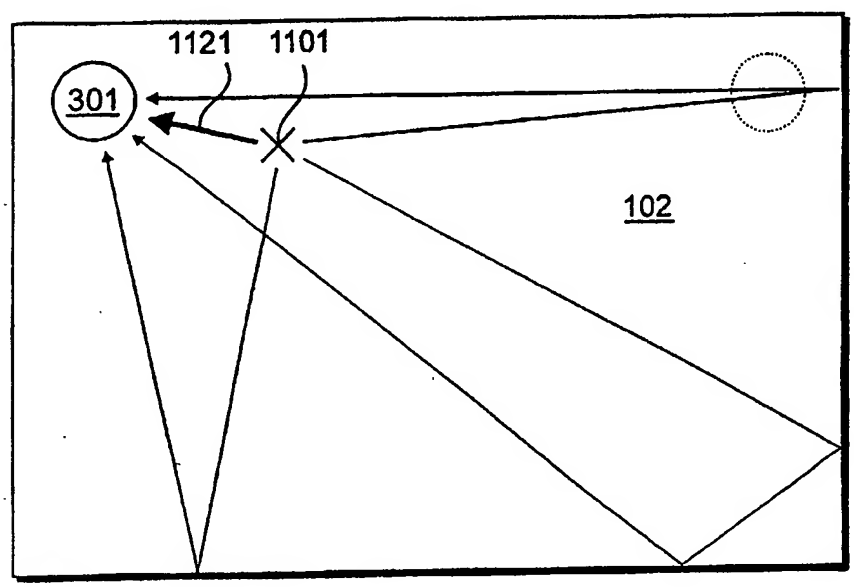

Figure 11

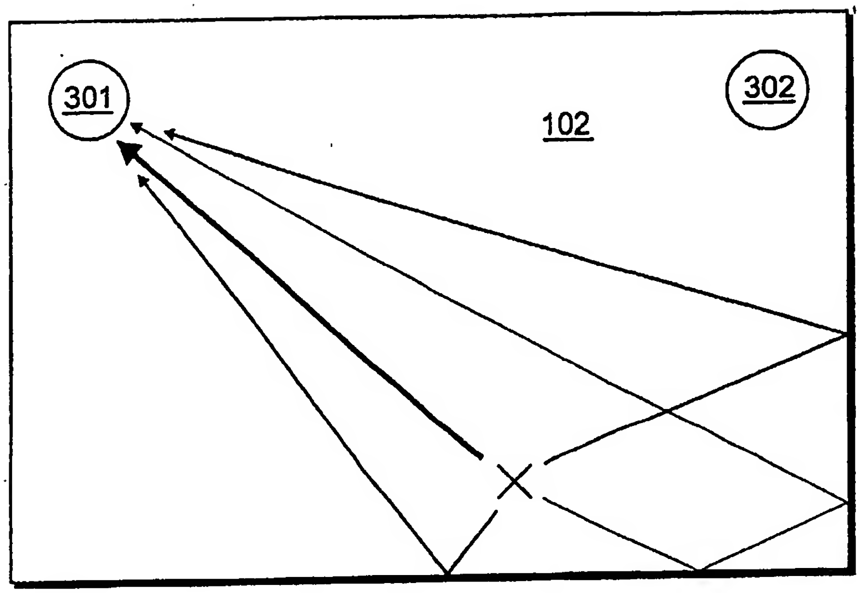

Figure 12

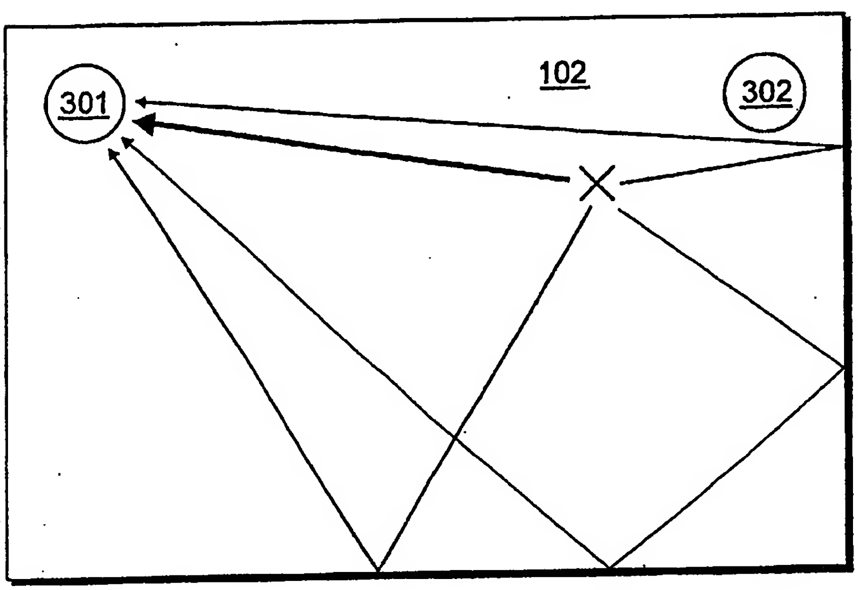

Figure 13

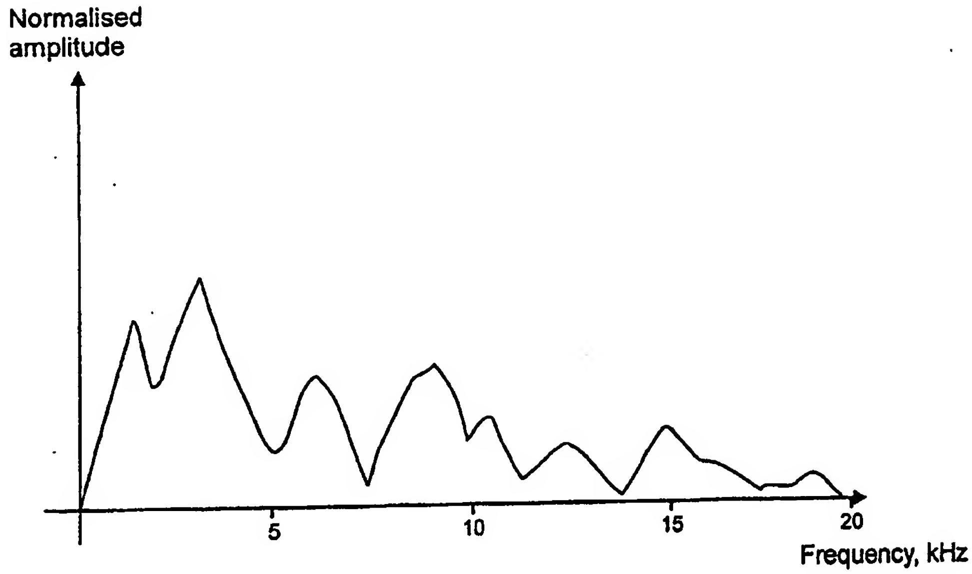

Figure 14

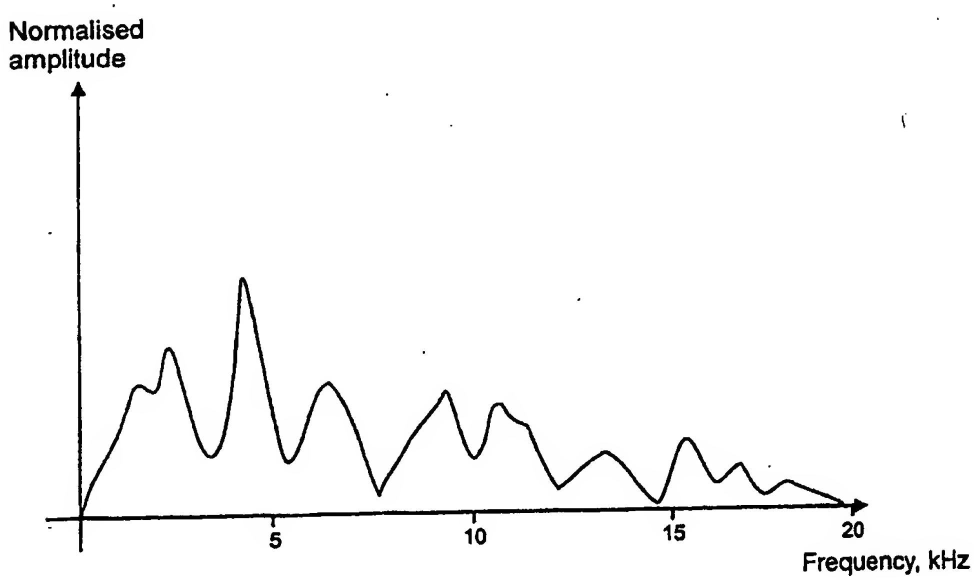

Figure 15

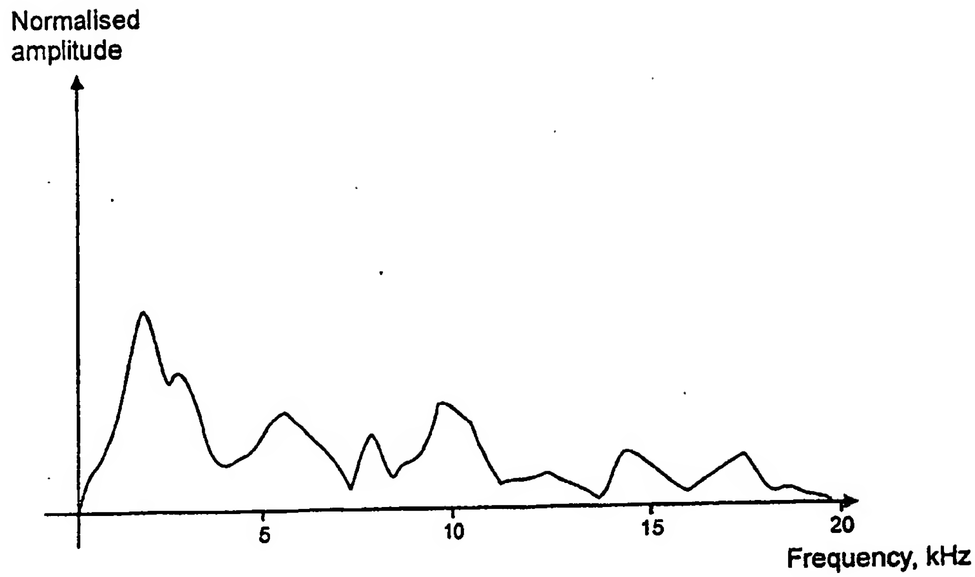

Figure 16

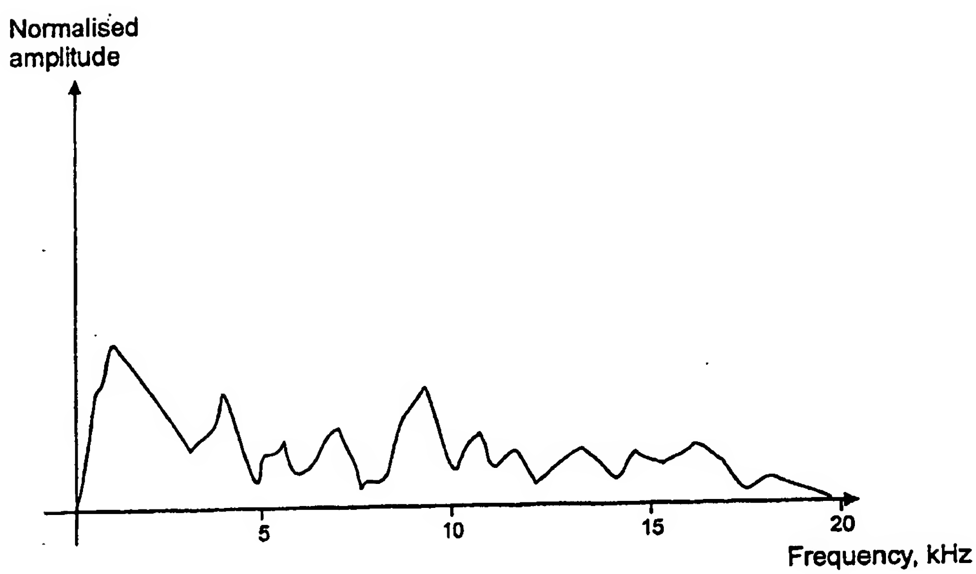

Figure 17

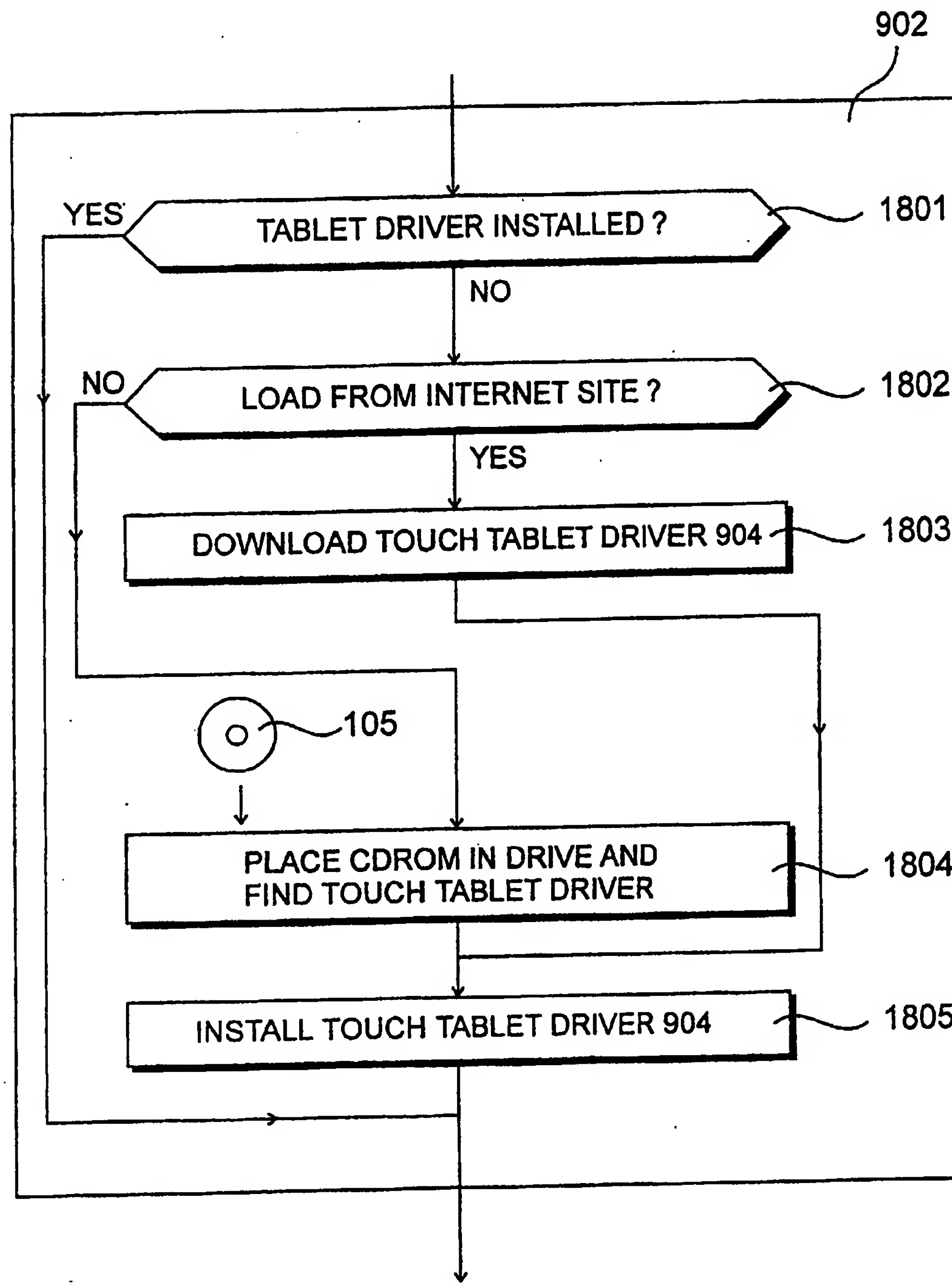
902
TABLET DRIVER INSTALLED ?
1801
YES
NO
LOAD FROM INTERNET SITE ?
1802
NO
YES
DOWNLOAD TOUCH TABLET DRIVER 904
1803
105
PLACE CDROM IN DRIVE AND
FIND TOUCH TABLET DRIVER
1804
INSTALL TOUCH TABLET DRIVER 904
1805

Figure 18

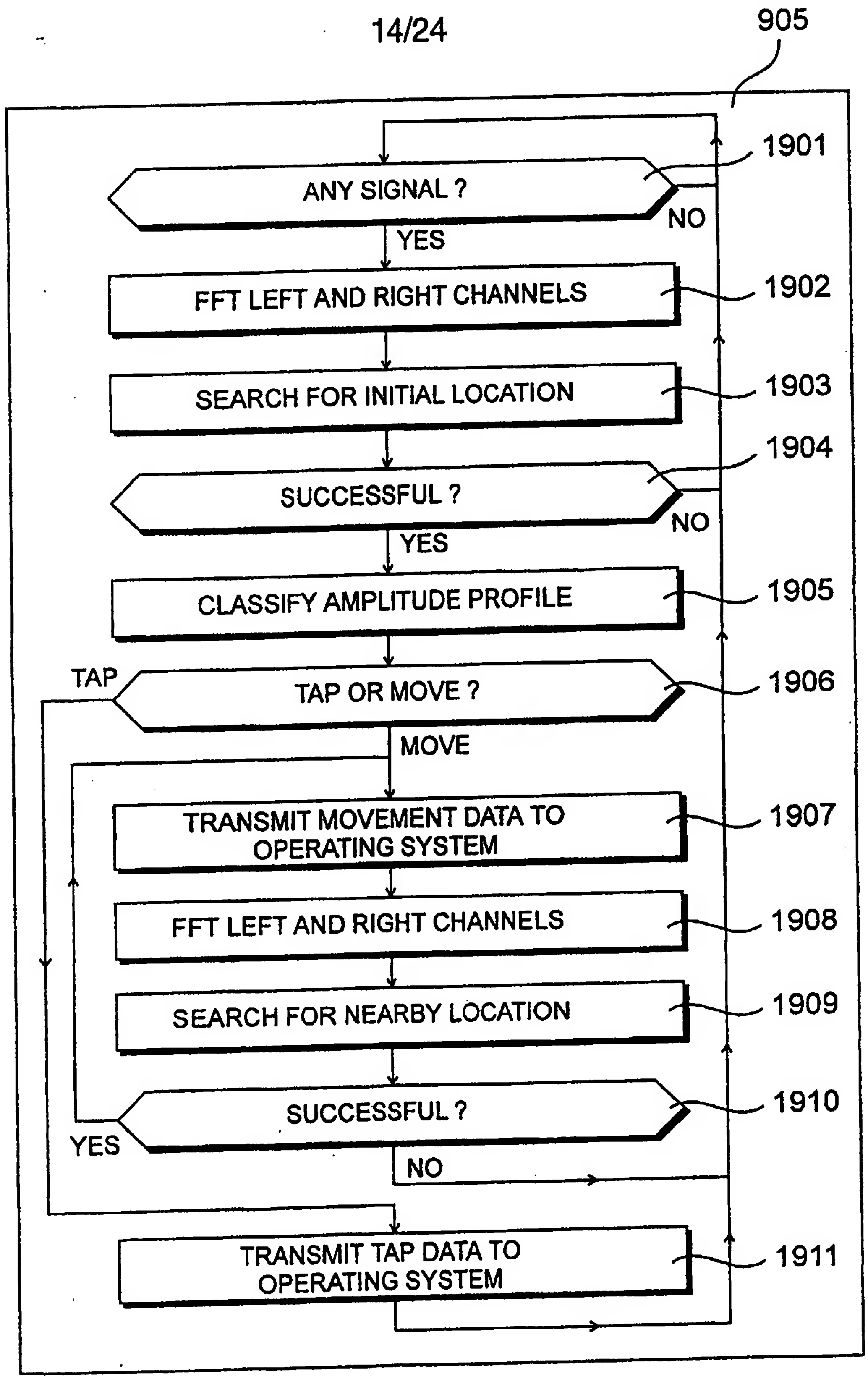
905
1901
ANY SIGNAL ?
NO
YES
FFT LEFT AND RIGHT CHANNELS
1902
SEARCH FOR INITIAL LOCATION
1903
1904
SUCCESSFUL ?
NO
YES
CLASSIFY AMPLITUDE PROFILE
1905
TAP
TAP OR MOVE ?
1906
MOVE
TRANSMIT MOVEMENT DATA TO OPERATING SYSTEM
1907
FFT LEFT AND RIGHT CHANNELS
1908
SEARCH FOR NEARBY LOCATION
1909
SUCCESSFUL ?
1910
YES
NO
TRANSMIT TAP DATA TO OPERATING SYSTEM
1911

Figure 19

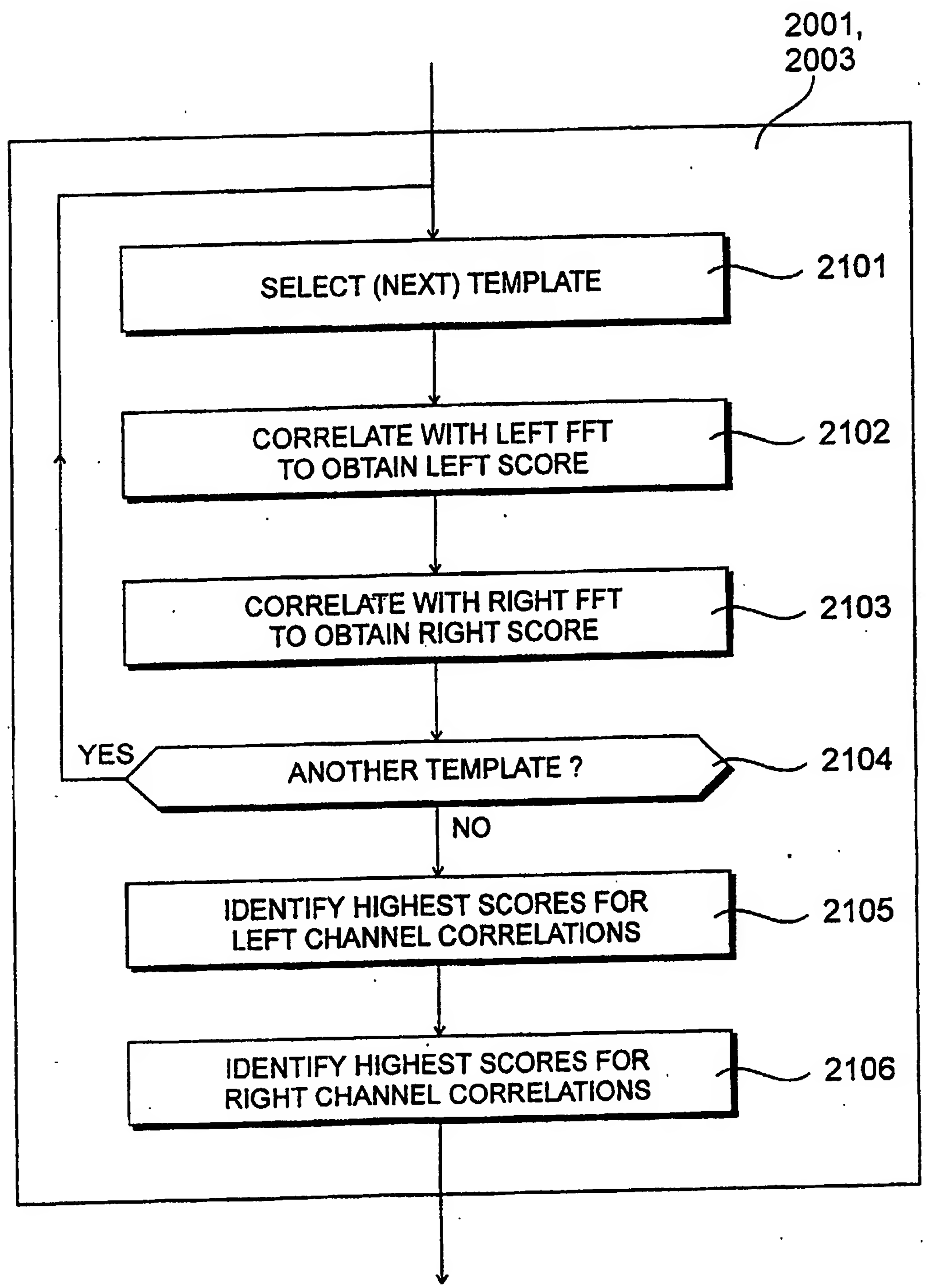
2001,
2003
SELECT (NEXT) TEMPLATE
2101
CORRELATE WITH LEFT FFT
TO OBTAIN LEFT SCORE
2102
CORRELATE WITH RIGHT FFT
TO OBTAIN RIGHT SCORE
2103
YES
ANOTHER TEMPLATE ?
2104
NO
IDENTIFY HIGHEST SCORES FOR
LEFT CHANNEL CORRELATIONS
2105
IDENTIFY HIGHEST SCORES FOR
RIGHT CHANNEL CORRELATIONS
2106

Figure 21

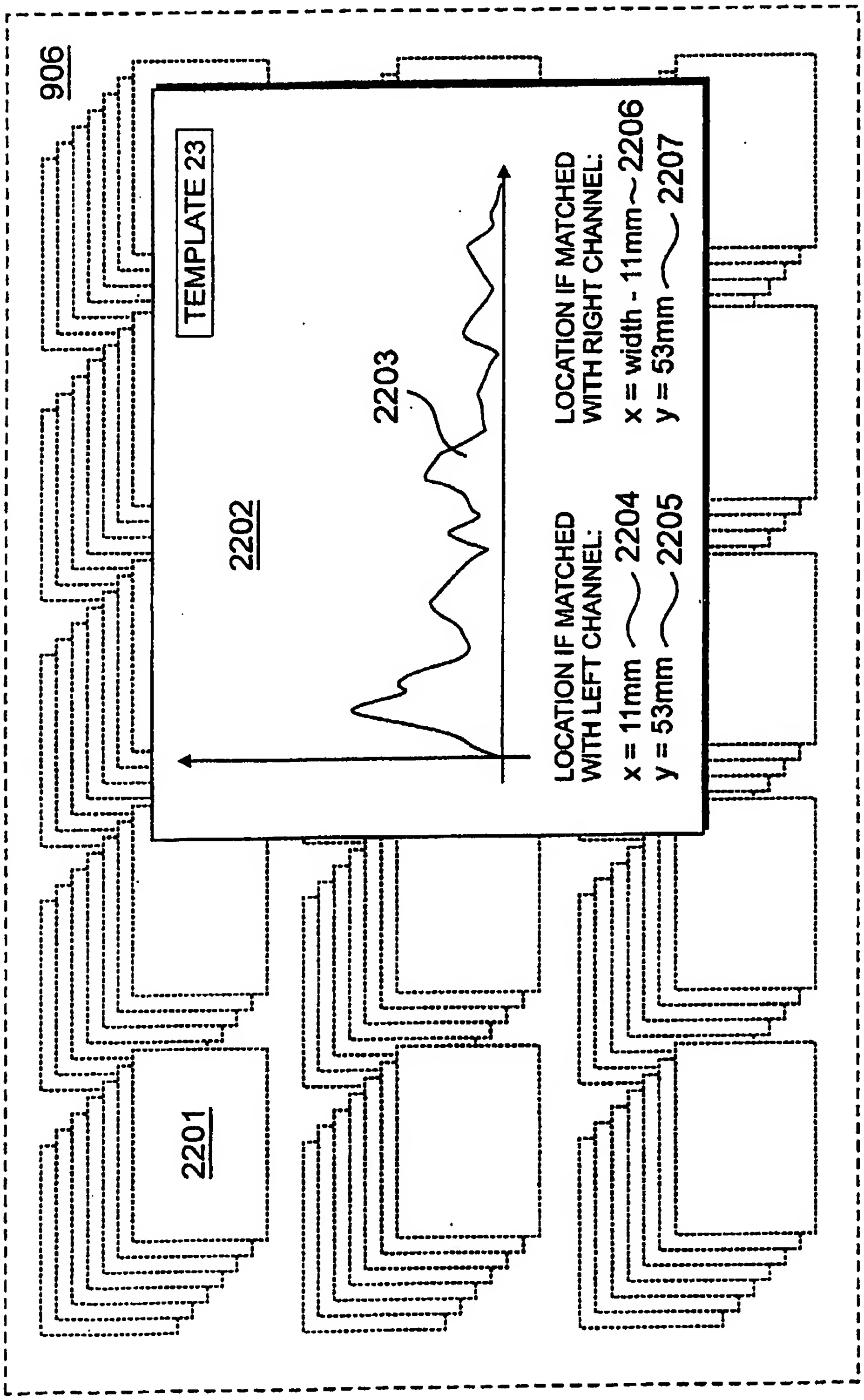
906
TEMPLATE 23
2202
2203
LOCATION IF MATCHED WITH LEFT CHANNEL:
x = 11mm
2204
y = 53mm
2205
LOCATION IF MATCHED WITH RIGHT CHANNEL:
x = width - 11mm
2206
y = 53mm
2207
2201

Figure 22

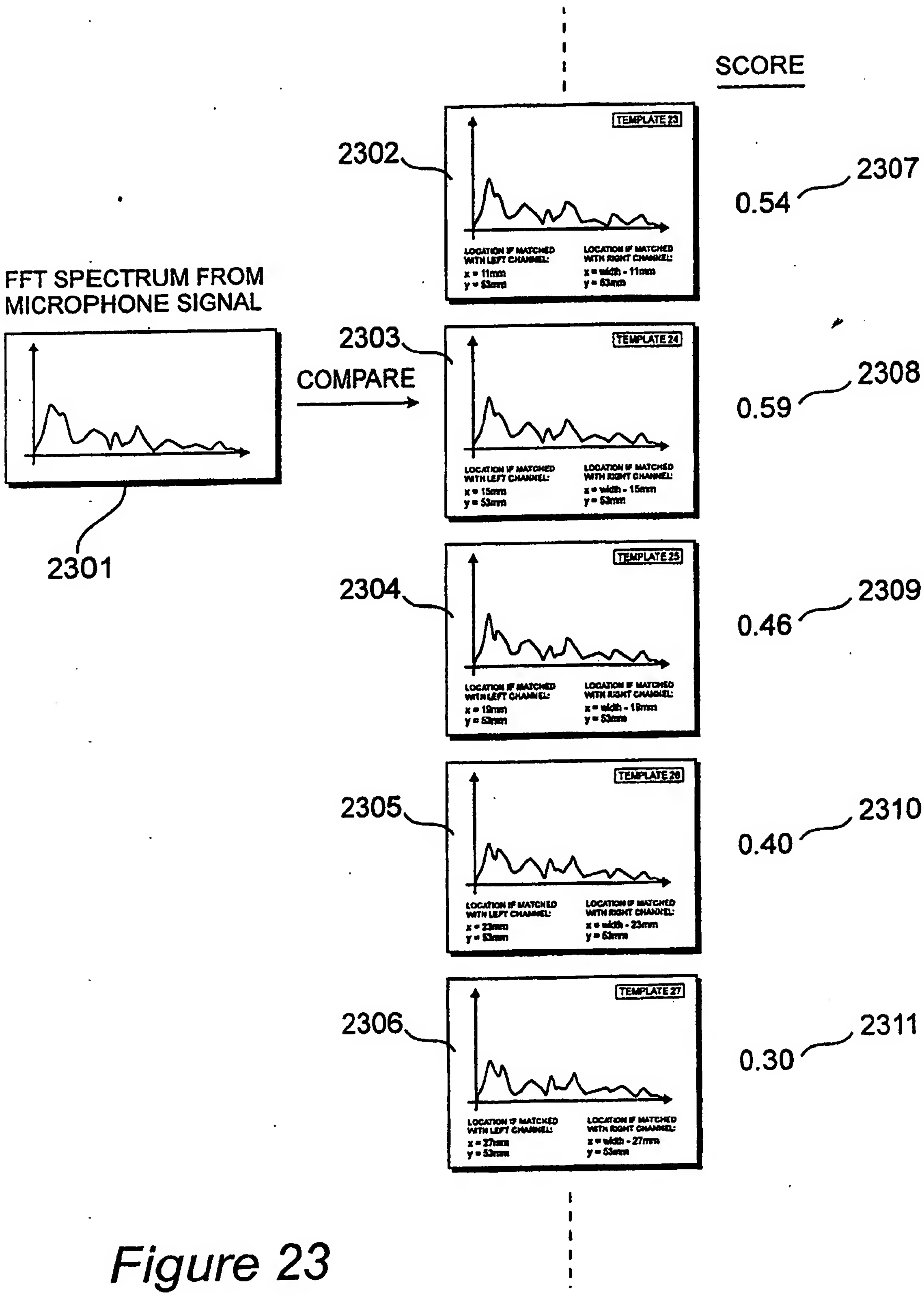
SCORE
FFT SPECTRUM FROM
MICROPHONE SIGNAL
COMPARE
2301
2302
2303
2304
2305
2306
TEMPLATE 23
TEMPLATE 24
TEMPLATE 25
TEMPLATE 26
TEMPLATE 27
LOCATION IF MATCHED
WITH LEFT CHANNEL:
LOCATION IF MATCHED
WITH RIGHT CHANNEL:
0.54
0.59
0.46
0.40
0.30
2307
2308
2309
2310
2311

Figure 23

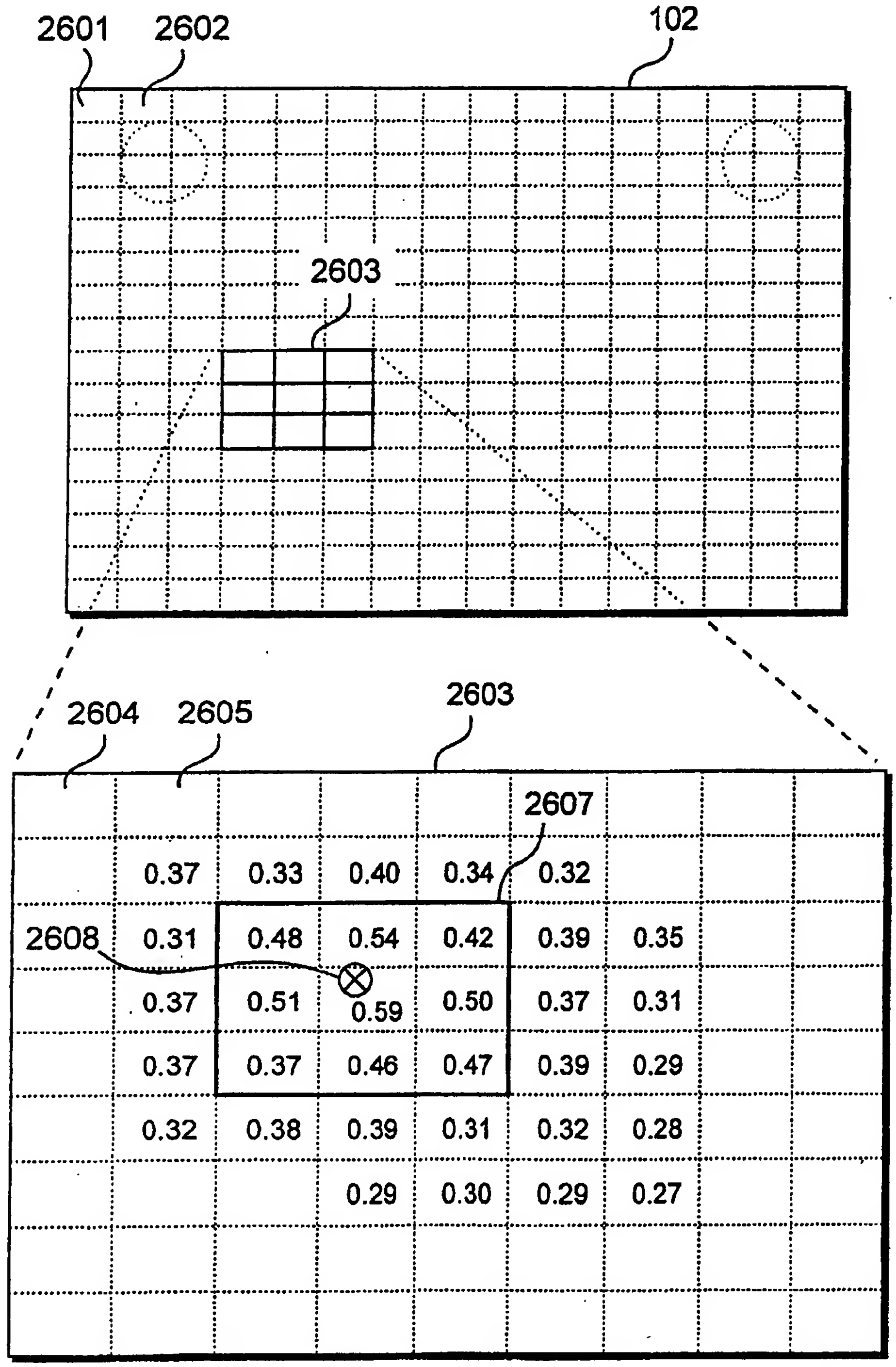
2601
2602
102
2603
2603
2604
2605
2607
2608
0.37 0.33 0.40 0.34 0.32
0.31 0.48 0.54 0.42 0.39 0.35
0.37 0.51 0.59 0.50 0.37 0.31
0.37 0.37 0.46 0.47 0.39 0.29
0.32 0.38 0.39 0.31 0.32 0.28
0.29 0.30 0.29 0.27

Figure 26

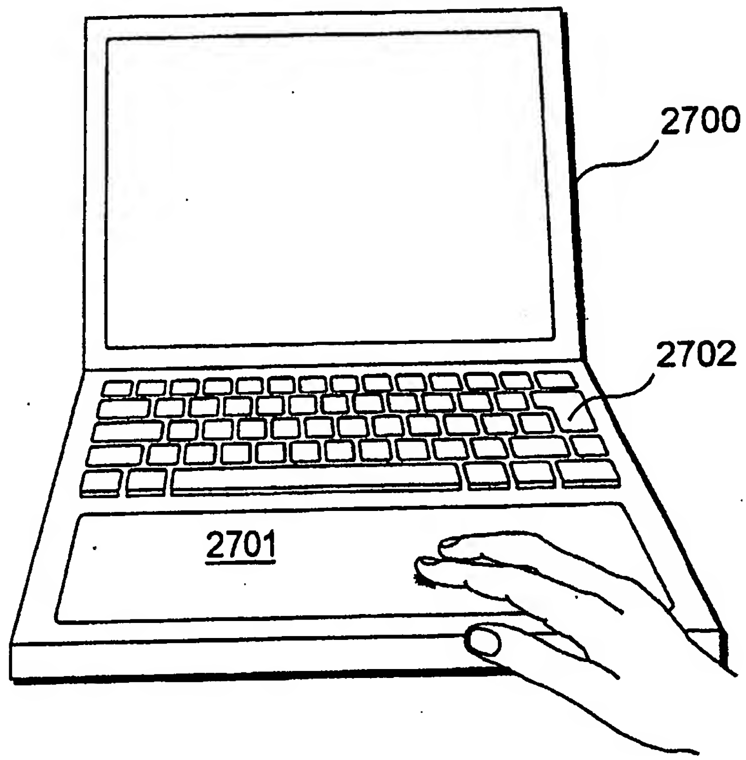

Figure 27

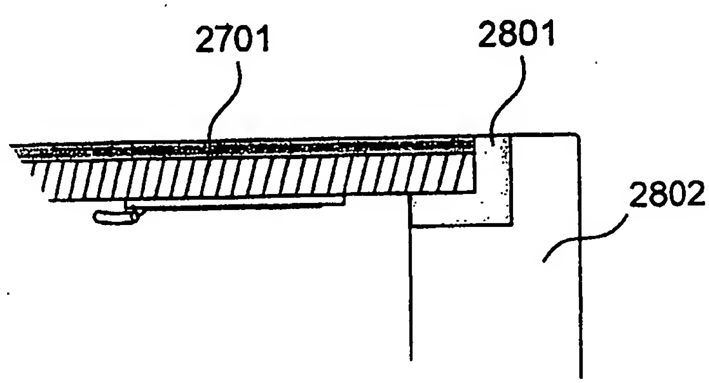

Figure 28

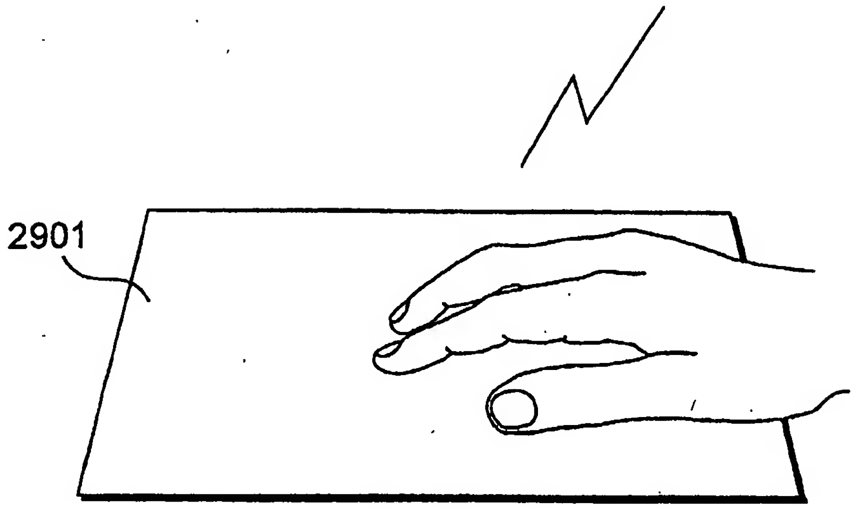

Figure 29

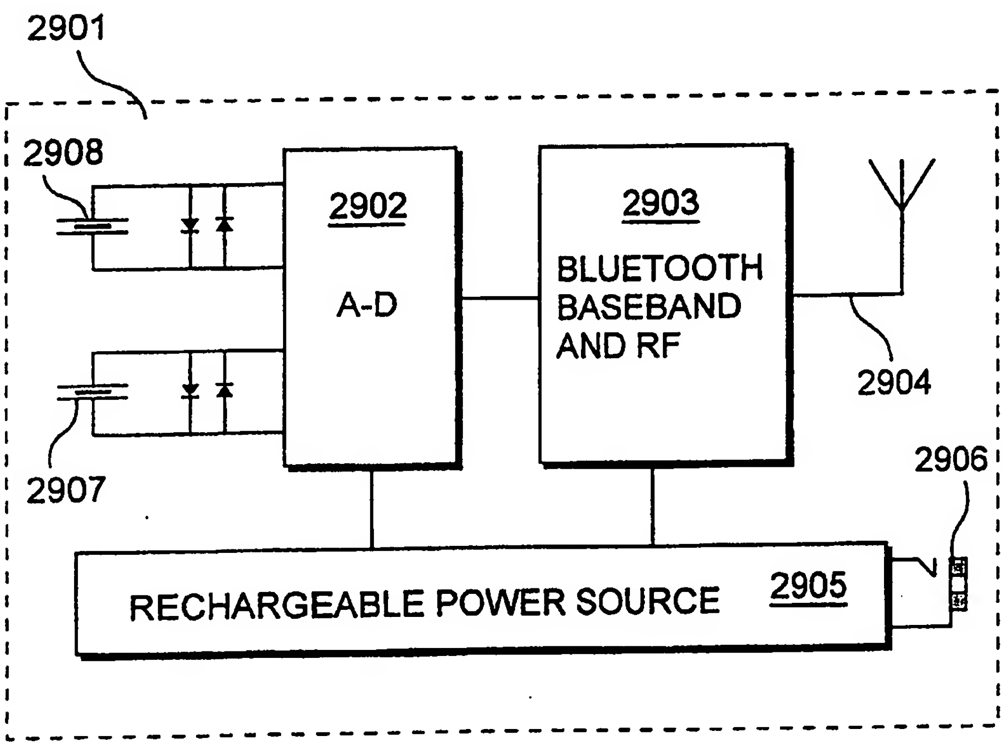

Figure 30

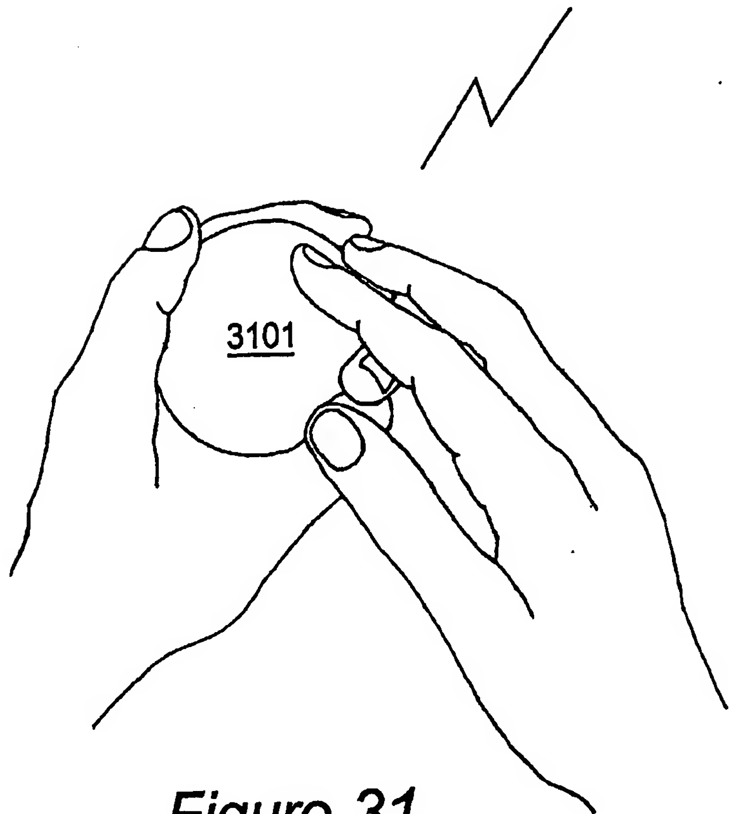

Figure 31

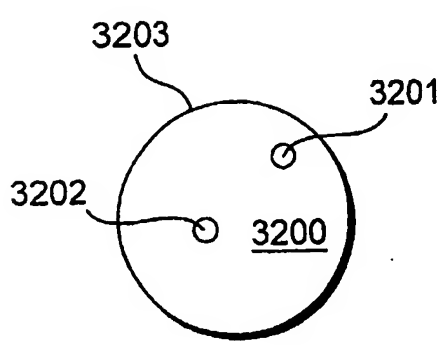

Figure 32

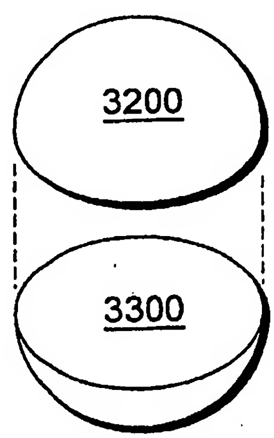

Figure 33

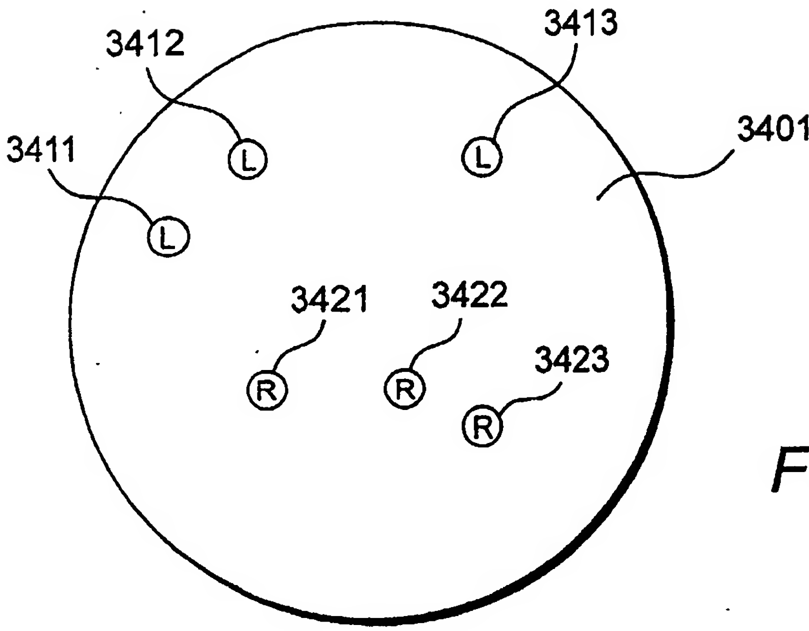

Figure 34

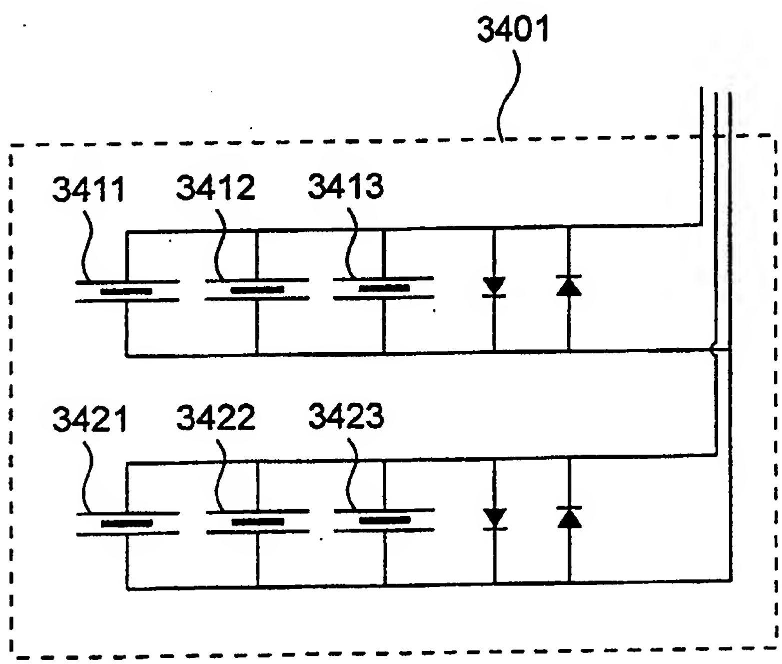

Figure 35

2385125

OFFICIAL TITLE: Input Apparatus

C00021437

Field of the Invention

The present invention relates to an input apparatus for a processing system, such as a personal computer. In particular, the present invention relates to an apparatus having a surface for touch events, such as movement of a finger, that can be used as a pointing device.

Introduction to the Invention

The evolution of powerful low cost computing systems has been accompanied by a parallel evolution of the human-machine interface. The interface includes both hardware and software components: a general purpose computer is provided with a pointing device and a keyboard for text input, and a monitor for displaying information. The software operates with the pointing device to enable the user to identify a preferred item among several items displayed on the monitor. Once the preferred item has been identified by the user, further operations are made within this context. With a high resolution monitor, a detailed display can be established, including many hundreds or thousands of such items that the user can identify. As a result, pointing device operations have become frequent and unavoidable.

Tracking the movement of a finger across a surface would seem to be a good alternative to common pointing devices. Known devices that achieve this are incorporated into laptop computers. Two types of such sensor are known, a resistive type and a capacitive type. Both of these suffer from the

restriction that only one point of physical contact can be made with the surface. In a large sensor, the user must avoid touching the surface with the wrist or any part of the hand other than the moving fingertip. This would make use of large area versions of these sensors at least as uncomfortable as using an ordinary mouse. As a result, finger tracking is constrained to a relatively small area, resulting in considerable inconvenience.

A capacitive sensor that permits multiple touch points is developed under the name "Fingerworks", by Fingerworks Corporation, Delaware, USA. The sensor is described in International Patent Application WO 938149A1. A profile of touch proximity to a surface is generated by measuring capacitance at a large number of individually amplified sensors. The electronic circuitry is expensive, and complex software is required to differentiate between a moving fingertip and other parts of the hand.

An acoustic touch panel for detecting finger taps and their location is described in European Patent Application EP 0474232A2, Four microphones at the corners of a rectangular touch panel pick up the same tap signal at different times, according to how far across the panel the sound has to travel. These times are compared and triangulation is used to identify the tap location. However, the apparatus does not track continuous movement of a fingertip across the panel, and so could not be used as a pointing device.

Another type of acoustic mode input device is described in German Patent DE 4143364A1. This takes the form of a tablet having a rippled

surface. As a stylus is moved across the surface, a noise is generated when the stylus tip encounters a ripple. Four microphones in corners of the tablet pick up these sounds, and triangulation is used to obtain an estimate of the stylus position. More precise differential movement tracking can be obtained by analysing sidebands imposed upon a naturally resonant frequency mode of the stylus. A limitation with this system is that it requires a stylus, and it has the same functionality as the stylus-operated graphics tablets that are in widespread use. The graphics tablet does not replace a mouse, because it is necessary to pick up a stylus.

Continuous tracking of finger position in an acoustic sensor is described in International Patent Application PCT/GB00/04635, by the present applicant. As a fingertip moves across a surface, natural friction results in the generation of wideband acoustic noise. This will occur with any smooth but unpolished surface. The distance from the fingertip to each of several microphones is identified by analysis based on an attenuation model for sound waves propagating through the surface. Triangulation with information from at least three microphones is then used to identify the location of the moving fingertip. However, the attenuation model describing the acoustic properties of the surface does not provide a high enough level of accuracy for a pointing device. Furthermore, the requirement for at least three microphones would prevent such a device from being connected directly to the audio input of a computer soundcard. Additional analogue to

digital and interface circuits would be required.

Summary of the Invention

It is an aim of the present invention to provide an improved apparatus for tracking the movement of a fingertip against a surface.

According to a first aspect of the invention there is provided an apparatus for inputting data into a processing system, comprising a fricative surface for receiving user finger movements made against that surface, and transducer means arranged to receive sounds arising from the movement of a user's fingertip across said fricative surface. The surface has a direct path and at least one reflection path for acoustic conduction of surface sound to said transducer means, so that interference between said paths occuring at said transducer means results in interference artefacts that characterise the location of a fingertip on said surface.

According to a second aspect of the invention there is provided a method of inputting data into a processing system, in which signals relating to user input movements on a surface are analysed to generate input data for said processing system. The said signals are generated by transducer means in response to sound arising from a user input gesture being made upon said surface; surface sound is transmitted to the transducer means by a system of acoustic transmission paths, including a direct path and at least one reflection path, and the location of the sound on the surface is

identified by processing a characteristic of said path system with characteristics of other path systems of known surface location.

According to a third aspect of the invention there is provided a method of processing a signal to determine a location of a sound source on a surface, wherein said signal has a characteristic that is determined by acoustic reflections in said surface, comprising the steps of: (1) characterising said location by transforming said signal to produce transformed data that reveals reflection artefacts and (2) identifying a location for said sound source by processing said transformed data with a reflection model for said surface.

Brief Description of the Drawings

The invention will now be described by way of example only with reference to the accompanying drawings, in which:

Figure 1 shows a computer system, including a touch tablet, and a computer;

Figure 2 details operation of the touch tablet shown in Figure 1;

Figure 3 shows a plan view of the touch tablet shown in Figure 1;

Figure 4 shows a cross-sectional view of the construction of the touch tablet shown in Figure 1;

Figure 5 shows several alternate touch tablet configurations;

Figure 6 details an enhancement of the acoustic properties of the

touch tablet shown in Figure 1;

Figure 7 shows a circuit diagram of the touch tablet shown in Figure 1, including a stereo connection for a sound card;

Figure 8 details key components of the computer shown in Figure 1, including a processor, a memory and a standard computer sound card suitable for connection to the circuit shown in Figure 7;

Figure 9 details the contents of the memory shown in Figure 8, including installer instructions and a touch tablet driver comprising instructions and templates;

Figure 10 summarises the invention and shows the main acoustic transmission paths from a sound source (such as a moving fingertip) to an asymmetrically located transducer, forming an acoustic transmission system unique to the location of the sound source on the touch tablet;

Figures 11 to 13 detail different transmission systems for several locations of a sound source on the touch tablet shown in Figure 1;

Figures 14 to 17 detail respective spectral characteristics of the transmission systems shown in Figures 10 to 13;

Figure 18 summarises the effect of the installer instructions shown in Figure 9;

Figure 19 summarises operations performed by the processor shown in Figure 8 in response to the touch tablet driver instructions shown in Figure 9, including steps for searching for a sound location and a step of combining

left and right results;

Figure 20 details the operations performed when searching for a sound location in Figure 19, including steps in which a location is identified;

Figure 21 details the operations performed during the step of identifying a sound location shown in Figure 20, including correlation steps;

Figure 22 details the templates shown in Figure 9;

Figure 23 illustrates the correlation steps performed in Figure 21;

Figure 24 defines the linear correlation equation used in Figure 21;

Figure 25 defines the step of combining left and right results shown in Figure 19;

Figure 26 illustrates the searching process summarised in Figure 20;

Figure 27 shows an alternative embodiment of the invention, in the form of a touch tablet in a laptop computer;

Figure 28 illustrates an aspect of the construction used in the laptop embodiment shown in Figure 27;

Figure 29 shows a further alternative embodiment, in which the touch tablet contains a radio link to the computer shown in Figure 1, or to another processing system;

Figure 30 details the circuitry of the touch tablet shown in Figure 29;

Figure 31 illustrates another alternative embodiment, in the form of a spherical input device comprising two hemispheres;

Figure 32 details microphone placement in one of the hemispheres

shown in Figure 31;

Figure 33 illustrates combination of two hemispheres of the type shown in Figure 32 to form the spherical device of Figure 31;

Figure 34 shows an input device having parallel-connected transducers; and

Figure 35 shows the circuit diagram for the input device shown in Figure 34.

Detailed Description of The Preferred Embodiment

A personal computer system is shown in Figure 1, comprising a computer 101, a touch tablet 102, a keyboard 103, and a monitor 104. A CDROM disk 105 is provided for the installation of new instructions. The computer system is operated by a combination of text input on the keyboard 103 and graphical and cursor movement input using the touch tablet 102. The monitor 104 displays a graphical user interface (GUI) that enables an operator of the system to enter text and navigate a wide variety of combined textual and graphical displays.

In the computer system shown in Figure 1, the touch tablet 102 operates as a pointing device, replacing a standard computer mouse. The touch tablet is operated by sliding movement or tapping of a fingertip directly on its surface. A sharp object such as a pencil can be used to enter handwriting into the system. The CDROM disk 105 includes instructions

and data necessary to establish a device driver in the computer 101, so enabling the touch tablet 102 to be used in place of a mouse.

The touch tablet 102 shown in Figure 1 is detailed in Figure 2. The palm of user's hand 201 can rest gently upon the surface of the touch tablet 102. When a fingertip is moved across the surface of the tablet 102, random noise is generated at the point of interaction between the finger and the surface, as indicated at 202. The noise is generated by a random process due to friction, and this will occur on any smooth but unpolished surface. The noise that is generated is similar in character to natural random noise generated by the wind, and the noise generated by thermal activities within semiconductor components. A surface capable of generating noise in this way is referred to as a fricative surface. A broad range of frequencies is generated continuously by the process of friction, and this continuous presence of noise at the location of the fingertip is what makes it possible to track its location.

A shorter sound is generated by tapping on the surface of the tablet 102, and this is suitable for roughly identifying the position of touch events analogous to the click of a computer mouse. The touch tablet 102 is connected to the computer 101 by a cable 203.

Known acoustic methods for detecting the location of a touch event rely on the presence of at least three microphones in order to perform triangulation in the two dimensions of the surface to locate the sound

source. The requirement of at least three microphones makes such apparatus expensive because of the need for at least three analogue to digital converters. This simple fact precludes operation of such a touch tablet with an ordinary computer without additional analogue to digital conversion and interface circuitry, as computers are generally supplied only with a stereo microphone input. Furthermore, although continuous fingertip tracking is described in PCT/GB00/04635 (by the present applicant), the analysis method which is described uses an attenuation model of the acoustic properties of the touched surface, which is not accurate enough for use in a pointing device.

The touch tablet 102 is further detailed in plan view in Figure 3. Under the surface of the tablet 102 are two microphones 301 and 302. These are piezo-electric transducers to which sounds are conducted from the location of the friction noise 202. The microphones are located near two corners of the tablet 102.

A cross-sectional view of the touch tablet 102 is shown in Figure 4. A smooth fricative surface 401 is provided so that a finger may move smoothly across it and generate noise. The preferred surface is Formica™. However, many surfaces are suitable, including fabric, paper and wood. The substrate 402 acts in combination with the surface 401 to define acoustic conduction in the tablet. Preferably the substrate is made from fibre-board, although wood with a specific grain direction may be used as

an alternative. Aluminium, dense plastics and nylon are also suitable materials for the substrate 402. Honeycomb construction of a symmetric or asymmetric form may be helpful in obtaining a substrate with the most effective acoustic properties. The piezo-electric microphones 301 and 302 are bonded to the substrate 402. The piezo-electric elements are formed on thin brass discs, so that once bonded to the substrate they become acoustically part of the substrate. The microphones 301 and 302 may be embedded in any way into the surface 401 and or substrate 402, in order to most efficiently generate electrical signals from sounds propagating across the tablet 102. Beneath the substrate is a layer of felt 403, which provides acoustic insulation from the base 404, which is a thin sheet of plastic.

For simplicity in the description of the acoustics properties of the touch tablet 102 and other embodiments, the substrate is considered a part of the surface, and the surface will be considered as including any physical parts of the tablet that significantly affect acoustic characteristics relevant to touch detection and location, except when explicitly stated otherwise.

The location of the microphones 301 and 302 on the touch tablet 102 is asymmetric. The tablet 102 provides a two dimensional area for touch detection. However, the microphones are not arranged symmetrically with respect to both dimensions. There is an axis of symmetry half way between the microphones that divides the tablet in two, but this is the only axis of symmetry. The arrangement of the microphones will be considered

as being asymmetric because there are fewer axes of symmetry (there is only one) than there are dimensions (there are two) in which the sound source is located. The invention provides this asymmetry in a touch tablet so that two-dimensional location of a sound source can be achieved using only two microphones.

Other possible asymmetric touch tablet configurations are shown in Figure 5. A rectangular touch tablet is shown at 501, having only one microphone. There are advantages to using two microphones. However, in theory only one is required, and in some embodiments this may be of practical benefit. Microphone placement on another rectangular touch tablet 520 is more complex than that shown in Figure 3. In the preferred embodiment shown in Figure 3, microphones are positioned either side of a single axis of symmetry half way between the microphones and dividing the tablet in two. This configuration reduces the amount of processing required when finding the sound source location. However, in some situations, additional accuracy may be obtained from an arrangement such as that shown at 520, making the extra processing requirement worthwhile. Other configurations of the invention are shown at 530, 540, 550 and 560. These are not intended to be exhaustive, and are merely illustrations of the requirement for microphone asymmetry. A large number of microphones is shown at 550, where the asymmetric condition is still satisfied, but more than two microphones is being used. This provides an extremely robust

touch location system which may be useful in a noisy environment. Any of these examples 510, 520, 530, 540, 550 and 560 could be plan views of a three-dimensional shape, with the surface being curved in a third dimension.

The asymmetry of the touch tablet 102 results in a high complexity of acoustic phenomena that are used to unambiguously identify the location of a noise source. Touch tablets designs such as 550 and 560 shown in Figure 5 are fairly complex. However, a regular shape for the touch tablet may be preferable, such as the rectangle of the preferred embodiment 102, but in which acoustic complexity needs to be increased to enable noise source location to be performed most accurately. The acoustic shape can be modified without changing the physical shape, and this is illustrated in Figure 6. In this alternative embodiment, the tablet 102 has a substrate 402 made from wood having a grain in a particular direction. The direction of the grain is illustrated by vertical lines 601. The velocity of sound in wood is greater in the direction of its grain. When constructed in this way, the tablet 102 has an acoustic width to height ratio 602 that is different from its physical width to height ratio, and this results in a beneficial increase in the complexity of acoustic artefacts which can be used to identify sound location in a rectangular touch tablet. Additional modifications are possible. For example, the thickness of the substrate 402 can be varied in a regular or irregular pattern or texture.

The circuit components for the touch tablet 102 are shown in Figure 7. Each microphone is a piezo-electric transducer in the form of a disk. A thin brass disk 702 has a deposit of piezo-ceramic material 703 about 0.5mm in thickness. The surface of the piezo-ceramic material is silvered, and electrical connections 704 are established with the silvered surface and the brass disk 702. In the circuit shown in Figure 7, each transducer 301 and 302 has voltage limiting diodes 705, 706, 707 and 708, which prevent excessive voltages developing that could damage microphone input circuits in the computer 101. The transducer signals are connected by a screened audio cable 709 to a 3.5mm stereo plug 710.

The computer 101 shown in Figure 1 is detailed in Figure 8. A Pentium RTM central processing unit (CPU) 801 executes instructions held in one hundred and twenty-eight megabytes of main memory (RAM) 802, to perform manipulations of data also stored in the main memory 802. Instructions and data are permanently stored on a non-volatile hard-disk drive 803. Instructions for the processor may be installed from the CDROM 105 inserted into a CDROM/DVD drive 804. A video card 805 receives graphical drawing commands from the processor 801 to render images on the screen of the monitor 104.

A sound card 806 receives audio signals from the touch tablet 102 through its microphone input socket, which accepts the plug 710 shown in Figure 7. The sound card 806 converts analogue electrical signals from its

microphone input into pairs of sixteen bit samples at a rate of 44100 left and right samples per second. This data stream is made available to applications running on the computer, by transfer between the sound card 806, the processor 801 and the main memory 802. The sound card is also able to receive sound samples from applications and supply these to an amplifier, headphones or a small pair of loudspeakers that can be connected to the computer 101. Stereo sound cards of this type are built in to most general purpose computers. Often, the microphone input is of a low quality, with the analogue to digital conversion process having an effective accuracy of much less than sixteen bits. However, the touch tablet does not require significantly high quality analogue to digital conversion.

A universal serial port 807 connects the keyboard 103 to the computer. A modem 808 facilitates connection to an Internet service provider (ISP) via an ordinary telephone line. Instructions and data may be installed from a site on the Internet, as an alternative to installation from the CDROM 105.

Initialisation of the computer is performed when it is switched on, in accordance with bootstrap instructions for the processor 801. Once the bootstrap process is completed, the user typically starts and uses a number of software applications, such as a word processor, email and a web browser. These applications are often held in memory 802 at the same time so that the user may transfer data between them conveniently, and display

them in several overlapping windows on the monitor 104.

The contents of the main memory 802 are shown in Figure 9. A Windows XP RTM operating system 901 provides a hardware-neutral application programming interface (API) for several applications running on the computer 101. The operating system includes installer instructions 902 for installing new applications or other types of instructions and data. Several device drivers 903 are provided to enable the operating system to co-operate with specific hardware devices in the computer system 101. For example, a device driver is provided for the video card 805 and for the sound card 806. A touch tablet device driver 904 is provided, and this includes touch tablet instructions 905 and templates 906. Several applications 907, 908 and 909 are held in the memory 802, including their instructions and their data. The touch tablet driver 904 allows the applications to receive user commands from the touch tablet as if they were operations of an ordinary mouse or other pointing device. The many applications that are available for a computer 101 of this type can operate directly with the touch tablet 102 without modification.

The main operations performed by the touch tablet driver 904 are the analysis of audio signals from the microphones 301 and 302. From this analysis, the same data that would ordinarily be generated by an ordinary pointing device can be generated by the touch tablet driver 904 in response to user finger movements and taps.

The analysis is based upon a reflection model of sound wave propagation in the touch tablet 102. The invention is explained in Figure 10, in which reflection paths of sound wave propagation are illustrated. The location of the fingertip moving across the surface of the tablet 102 is shown by a cross at 1001. Sound is transmitted outwards from this source 1001 through the plane of the touch tablet 102. This results in a system of several acoustic transmission paths from the source 1001 to the microphone 301.

The strongest transmission paths are shown. A single direct path 1011 provides the shortest route from the source 1001 to the microphone 301. Another path 1012 results from a single reflection 1013 against the near edge 1014 of the tablet 102. Another path 1015 results from a single reflection against the right edge 1016 of the tablet 102. A double reflection path 1018 results from a first reflection 1019 against the near edge 1014 and a second reflection 1020 against the right edge. The relative strengths of the direct, single reflection and double reflection paths are indicated by the thickness of their lines. Each reflection results in an attenuation of the sound. Many other paths are present in the tablet, but are omitted for the sake of clarity. The combination of all such paths is considered as a system. For an asymmetric transducer location 301, there is a unique characterising system for every possible sound location 1001.

Each path in the system shown in Figure 10 has a different

transmission time, so the original sound is combined in several different delayed versions as it is converted into electrical form by a transducer 301. The magnitude of each delayed version is also different. Constructive and destructive interference occurs where the paths meet at the microphone. The interference pattern is different for each frequency in the spectrum. Since the sound is noise of a relatively continuous spectrum, the spectrum of sound received at the microphone 301 provides a clear impression of interference artefacts in the frequency domain. As the location of the sound source moves, its characteristic spectrum evolves also. Since the interference results from combination of a direct path 1011 with reflection paths, the spectrum may be considered as revealing reflection artefacts.

The noise generated by a moving fingertip may be partially or entirely stochastic in origin, and has an overall smooth spectral shape, as is the case with 1/f noise. The overall shape of the amplitude probabilities through the spectrum is smooth. Constructive and destructive interference at the microphone 301 modifies the spectrum sharply, from a smooth into a complex shape. It is this complexity that enables the location of a sound source to be identified.

In the preferred embodiment, reflections are caused by the sound reflecting from edges of the tablet 102. However, it is possible for anomalies to be present in the tablet, so that reflections can occur from parts other than the edges, which may help to uniquely characterise the

location of a sound. Constructional anomalies may be used therefore, both to modify the velocity of sound in the tablet medium as shown at Figure 6, and also to introduce additional causes of reflection. Both these effects can be used in the construction of a tablet to ensure unambiguous mapping between a sound source location and artefacts arising from its system of reflections.

The touch tablet 102 provides an apparatus for inputting data into a processing system. The surface of the tablet 102 permits movements of a user's fingertip to be formed upon it. These movements result in sounds 1001 being generated, and transducer means, in the form of microphones 301 and 302, picks up sounds arising from these movements. A pencil may be used in place of the user's fingertip, and a sheet of paper may be placed over the tablet's surface so that handwriting can be entered as data into the processing system. Acoustic transmission of the surface sound 1001 to transducer means 301 and or 302 is characterised by a system of paths 1011, 1012, 1015, 1018, including reflections 1013, 1016, 1019, 1020. The asymmetry of the transducer's location 301 and or 302, with respect to acoustic properties of the surface, has the resulting effect that sound source locations on the surface, such as location 1001, are uniquely characterised by their system of transmission paths 1011, 1012, 1015, 1018.

In Figure 11 a system for a different location 1101 is illustrated. The

direct transmission path 1121 is shorter, and the other main transmission paths also have different lengths and therefore transmission times and relative amplitudes. They are added together at the microphone 301 in accordance with their different amplitudes and delay times. Comparison between Figures 10 and 11 shows that the transmission systems differ significantly according to the location of the sound. The difference is complex, but varies smoothly as the fingertip moves continuously across the surface from location 1001 to location 1101. Systems for other sound source locations are illustrated in Figures 12 and 13.

Each location on the surface of the tablet 102 has its own unique system of sound propagation paths, which, through constructive and destructive interference at the transducer, can be revealed by transforming the transducer signals into location characterising data that reveals reflection artefacts. These artefacts exist because reflection paths combine with each other, and with the direct path, to form system characteristics which can be revealed by a transformation upon samples representing the sound received at one or several microphones.

The spectrum of frequency magnitudes is obtained by fourier transformation of the microphone. The resulting magnitudes of frequency components are indicative of the system, and hence the location of the sound source. These magnitudes are considered as a form of location chacterising data. The spectrum of a moving sound source at the location

shown in Figure 10 is shown in Figure 14. Corresponding spectral plots for the remaining three systems shown in Figures 11, 12 and 13, are shown in Figures 15, 16 and 17 respectively. These may be referred to for convenience as spectrograms. Each spectrogram is complex in shape, and uniquely characterises the transmission system for a sound source at a particular location on the tablet. Other forms of location characterising transformation may be possible, and the invention is not restricted to the use of the fourier transformation, or similar transformations.

It is possible to identify a sound source location in two dimensions uniquely from the reflection artefacts inherent in the signal from a single microphone 301. This reduction in the number of microphones compared to the prior art makes it possible to connect an acoustic touch tablet to the stereo input of an ordinary computer 101 without an interface circuit. Furthermore, the uniqueness of the mapping from reflection artefacts to sound location works at a high level of detail, so facilitating a level of resolution suitable for use in a pointing device, and also for handwriting input.

In the preferred embodiment, two microphones 301 and 302 are used. This has advantages for the rejection of false signals due to ambient noise. Furthermore, noise generated by a large area, for example the palm of the hand, will not be identified as having a specific location by the present system.

For the microphone arrangement shown in Figures 10 to 13, each microphone will see a different system of paths from a particular sound location 1001, except when the sound is located exactly half way between the two microphones. This does not result in any ambiguity, since the location is not determined by a process of triangulation as in the prior art. The two different microphone signals are used for confirmation and subsequent refinement of a location. The set of possible systems for the left microphone 301 is a mirror image of the set of possible systems for the right microphone 302. This relationship can be used to gain efficiency in computation and a reduction in the number of templates 906 that is required.

In some embodiments, such as touch tablet 540 shown in Figure 5, two possible locations may be characterised by the same system of paths. In this type of microphone arrangement, the combination of microphones is considered as providing the asymmetry required to unambiguously locate a sound. In this respect, therefore, the transducer means for the touch tablet is still considered as being asymmetrically located.

Instructions for the installer 902 may be run by the user in order to load the touch tablet driver 904 onto the computer 101. The effect of the installer instructions 902 is summarised in the flowchart shown in Figure 18. At step 1801 a question is asked as to whether the touch tablet driver 904 has already been installed. If so, no installation steps are necessary.

Alternatively control is directed to step 1802 where a question is asked as to whether the driver 904 is to be loaded from a site on the Internet. If not, control is directed to step 1804. Alternatively, at step 1803, the user connects to the Internet and downloads the installation package for the touch tablet driver 904. Thereafter control is directed to step 1805. If the touch tablet driver 904 is not to be downloaded from the Internet, control is directed to step 1804. The user places the CDROM disk 105 in the CDROM/DVD drive 804, and locates the file containing the installation package for the touch tablet driver 904. Thereafter control is directed to step 1805, where the touch tablet driver is installed, by a process of data decompression and storage on the hard disk 803, along with an update of associated files used by the operating system 901 to indicate the presence of the driver on the system and its characteristics. In the Windows XP RTM operating system, it is necessary to restart to computer system after installation of a device driver.

Operation of the instructions 905 of the touch tablet driver 905 are summarised in the flowchart shown in Figure 19. The steps of Figure 19 are operated in a continuous loop as a process among many other simultaneously executing processes that are established by the operating system 901. Touch events are of three different types. A transient tap, an initiation of a movement and a continuation of a movement. The driver waits for the start of a new touch event, which may be a tap event, or the start of

a finger movement. At step 1901 a question is asked as to whether any significant level of audio signal is being received by the microphone input of the sound card 806. If not, control is directed back to step 1901, and this sequence repeats until a suitable signal level is detected in the audio samples.

A fourier transformation is performed on a set of audio samples at step 1902. Samples received from the sound card 806 are received in packets of two hundred and fifty-six samples each for the left and the right microphones. A hanning window is applied to each set of two hundred and fifty-six samples, and then a fast fourier transform (FFT) is used to efficiently compute a frequency domain representation of the left and right signals. The frequency domain representation also has two hundred and fifty-six data items per channel, each representing the magnitude of a different frequency in the audio spectrum. The sample rate used by the sound card is 44.1 kHz, and the fourier transform is used to provide an indication of frequency component magnitudes up to 22.05 kHz. In an alternate embodiment, it is possible that another type of transformation may be used, for example a wavelet transformation. The purpose of step 1902 is to transform the audio samples from the sound card in a way that reveals location information about the sound source 202 in the form of reflection artefacts. When the magnitudes of frequency components are known, this reveals information about the system of acoustic transmission paths that is

unique to each possible sound location.

At step 1903 a search is performed for an initial location by processing the fourier transform of the left and then the right channel with templates 906. At step 1904 a question is asked as to whether the search for an initial location generated a valid location. If the answer is no, control is directed back to step 1901. Alternatively, control is directed to step 1905, where the overall amplitude profile of the original time domain audio samples is examined to determine a sharp or a smooth initial amplitude transition within the two hundred and fifty-six samples available. A sharp transition indicates a finger tap event, equivalent to a mouse click, and a smooth transition indicates a movement event. At step 1906 a question is asked as to whether a tap or a move event has been detected, and control is directed to step 1911 or step 1907 accordingly.

At step 1907 movement data is transmitted to the operating system 901 so that pointer movement information can then be supplied to applications 907, 908 and 909. At step 1908 another pair of left and right fourier transforms is obtained, in the manner described for step 1902. A search for a nearby location is made at step 1909. During the continuous movement of a fingertip across the surface, successive positions will be located near each other. This permits a much reduced set of templates 906 to be used for processing at step 1909, thereby reducing the amount of calculation necessary to track continuous movement of a fingertip. At step

1910 a question is asked as to whether the search for a nearby location has been successful. If so, control is directed to step 1907, where movement data is again transmitted to the operating system 901. The loop comprising steps 1907 to 1910 is repeated until valid incremental movements are no longer detected. After this, control is directed to step 1901, where a search is made for another initial position of a touch event. Tap information is transmitted to the operating system 901 at step 1911, whereafter control is directed back to step 1901.

Analysis to obtain the location of a touch event is performed similarly at both steps 1903 and 1909 in Figure 19. Both these are detailed in the flowchart shown in Figure 20. At step 2001 a rough sound location is identified, and a separate rough location is identified for each of the left and right channels. At step 2002 a question is asked as to whether locations indicated by left and right channels are close to each other. If not, it is presumed that the audio signal does not come from a point source of sound, and probably results from an ambient sound picked up by the tablet 102 or other unintentional source. Steps 2001 and 2002 are performed only when the flowchart of Figure 20 applies to step 1903, where an initial location is required. This is because, in the absence of any prior knowledge of the location of the sound source 202, it is necessary to consider all possible locations on the tablet 102. It would require a lot of processing to identify the sound location to a high level of accuracy in a single attempt, so

a rough location is obtained as a preliminary step. The remaining steps 2003 to 2007 are performed after an initial rough location is known. The rough location may be provided by steps 2001 and 2002, or from knowledge of the previous location occurring as part of a continuous finger movement, during which the previous position provides a good estimate of the current position. Methods such as position history-based dead reckoning (PHBDR) can be used to improve rough location estimation during continuous movement, and thereby reduce the amount of processing required still further.

Detailed searching of the local area around the estimated location is performed at step 2003. The same fourier transformations of the left and right channels are used in comparison with a selected subset of templates associated with the locality of the estimated location. As a result of step 2003, several template scores are generated, for each of the left and right channels. The template scores are combined with locations associated with each template by a process of interpolation performed at step 2004. This generates a more accurate pair of locations of the sound source.

At step 2005 a question is asked as to whether the left and right positions agree. If they are significantly different, the locations are discarded. Alternatively they are combined in proportion to their respective overall correlation scores to generate a single pair of x and y co-ordinates for the finger tap or move position. At step 2007 a flag is set in order to

indicate to step 1904 or step 1910 that the location of the sound has successfully been identified.

Identifying a sound location is achieved by comparing the left and right fourier transformations with a set of templates 906. This process, shown at steps 2001 and 2003 in Figure 20, is detailed in Figure 21. At step 2101 a first template is selected for comparison. At step 2102, a process of linear correlation is used to obtain a score of similarity between the shape of the spectrum from the left microphone, and the shape of the spectrum stored by the template. Each template corresponds to a known location on the tablet's surface, and scores generated in this way for templates corresponding to several positions can be compared to provide an indication of the location of the sound source 202.

At step 2103 the same template is correlated with the right channel spectrum, and a score indicative of the similarity is again generated. At step 2104 a question is asked as to whether another template is to be considered. If so, control is directed back to step 2101. These steps are repeated until all appropriate templates have been considered. When obtaining a rough location at step 2001, only templates corresponding to a sparse set of locations over the whole tablet are considered. When obtaining an accurate location at step 2003, only templates corresponding to locations in a local area around and including the rough location are correlated.

After template scores for the rough location have been obtained, at step 2105 a square of nine areas is identified. These correspond to the highest scoring square of nine templates that have been considered for the left channel. At step 2106 the same process is repeated for the right channel template scores.

To summarise: when obtaining a rough location, a first area is identified on the tablet. This area comprises locations associated with the best-scoring templates. Thereafter, when refining the search to a higher level of accuracy, a subsection of the large area is identified. The subsection area includes a central set of nine locations, Interpolation can then be performed, at step 2004, to determine the actual location of the sound source to a higher level of accuracy than that represented by the locations associated with the templates 906. Separate results for left and right are compared and combined, at steps 2005 and 2006, in order to identify the validity of the results, and to further increase their accuracy if they are validated.

The templates 906 shown in Figure 9 are detailed in Figure 22. The templates are data records 2201, of which two thousand three hundred and thirty-four are required for the entire template data set 906. The templates 906, along with instructions 905, form a reflection model of the touch tablet 102. An individual template is detailed at 2202. Each template includes a spectrogram 2203 representing the normalised spectrum of frequency

magnitudes of a simulated noise source at a particular location on the tablet surface. The spectrogram represents the magnitudes of each of two hundred and fifty six frequency components generated by the same mathematical transformation that is used at step 1902 in Figure 19. The location of the simulated noise source is stored at 2204 and 2205. Values 2204 and 2205 provide x and y co-ordinate values for left microphone 301 signals, whereas values 2206 and 2207 for the right microphone 302 are reflected in the x dimension, exploiting the fact that the locations of microphones 301 and 302 are reflections of each other about a single central axis. Value 2206 is equal to the width of the touch tablet 102 minus the corresponding value 2204 for the left channel. This arrangement cuts in half the number of templates that would otherwise be required.

The process of correlation shown at steps 2102 and 2103 in Figure 21 is detailed in Figure 23. The spectrum of frequency magnitudes generated for a microphone channel comprises two hundred and fifty six different frequency magnitudes, and is shown at 2301. This set of two hundred and fifty six data values is compared with the corresponding set of two hundred and fifty-six values in each template 2302 to 2306, to generate a respective score 2307 to 2311. The comparison is a process of linear correlation, resulting in a potential score range from minus one to plus one, reflecting the level of similarity between the shape of the microphone spectrum and the template against which it is being compared.

The linear correlation process used to compare a microphone spectrogram with a template is shown in the form of an equation in Figure 24. This is the standard linear correlation equation, in which the average of each data set is subtracted from each of its data items, and the product of paired values generated in this way is accumulated and then normalised to a score within the range minus to plus one. The microphone spectrum data set is indicated by the letter a, with subscript letter i being used to indicate selection of a particular frequency in a summation process. The template values are indicated by the letter n. This calculation results in the correlation coefficient, r, being generated, which is a measure of the similarity in shape of the two data sets that are being compared.

A value for r is generated for left and right channels separately when a template comparison is performed. In Figure 25, these are denoted r with a subscript L or R. Each template also has an associated x and y co-ordinate pair for each of left and right channels. The equation in Figure 25 combines left channel and right channel results to generate a single overall x and y co-ordinate pair to a high level of accuracy, detailing the process performed at step 2006.

The process of identifying a rough location and then refining it is illustrated in Figure 26. The tablet 102 is initially considered as comprising an overall area of sixteen by sixteen small rectangular areas 2601, 2602, at the centre of which is a point whose characteristic spectrum is recorded in

one of the templates 906. The initial rough search performed at step 2001 in Figure 20 considers these two hundred and fifty-six possible locations, finally identifying a rough location in the form of a three-by-three high-scoring region 2603 which has the highest set of correlation scores of any possible three-by-three area on this scale. An initial high scoring region 2603 is generated for each of left and right microphone channels separately. If these areas overlap, this is considered as indicating that a valid location can be identified from the sound source.

The initial area 2603 is then considered at a higher level of template resolution, in which each of the initial area subdivisions 2601, 2602 is considered as being further subdivided into smaller areas 2604, 2605. At the centre of each of these smaller areas is a point whose spectrum is recorded by one of the templates 906. The high scoring region 2603 is further examined by considering templates from the centre outwards, until it becomes clear that a peak region of three-by-three small areas has been identified. The peak region is shown at 2607. The correlation scores are shown for each of the small areas that has had to be considered in order to identify the peak region 2607. These values are processed (at step 2004) using bicubic interpolation. This identifies a finely resolved location 2608 to a higher accuracy than that provided by the raw x and y co-ordinates associated with each template. Two such locations are generated, one for each of left and right. These are combined at step 2006, assuming that they

are close enough together to be considered as producing a valid location.

In summary, the system of template analysis enables locations of a moving fingertip or finger tap to be identified. The system of templates 906 stores characteristics of a particular tablet design. The set of data defined by the templates, and the way in which they are used, may be considered as providing a reflection model. Preferably, template analysis is used. However, other techniques may be successfully applied to providing a reflection model. An alternative approach is neural network processing. This may be of particular benefit when a purpose-built neural network processor is used, thereby making it possible to implement the large number of artificial neurones that would be required for reflection model of the touch tablet 102.

Repeated analysis can track the movement of a continuously-made stroke of a fingertip or a pencil. The resulting movement data may be used in a conventional way, so that the tablet may be used as a pointing device to replace a mouse. As an alternative, movement of a finger can draw characters in a pictographic alphabet, which is of particular benefit for those alphabets that have too many characters for a conventional computer keyboard 103. The touch tablet may be seen as a way of inputting user data to a processing system, whether that be in the form of pointing actions to control a cursor on a screen, or in the form of direct data input, such as handwriting or input of pictographic characters.

In an alternative embodiment, the invention is used in a laptop computer, which is shown in Figure 27. The entire area 2701 in front of the keyboard 2702 can be used as a touch tablet, with the advantage that much longer continuous finger movements can be accommodated compared with the small area that is traditionally made available. There are several reasons why known laptop touch pads are so small. These include accuracy and cost. However, a major problem is that laptop users use the large area in front of the keyboard to rest their wrists while typing, and this would result in false signalling if a known sensor were to include this area. In the invention, only concentrated localised sources of sound are recognised as having distinct locations, and so it is possible to use the touch tablet area 2701 as support during typing without the usual problems occurring. In a further variation, the keyboard 2702 can be removed entirely, with the touch tablet 2701 extending over the entire area opposite the display. Text and alphanumeric input may be achieved by symbolic gesture input. A similar scheme might be employed in a smaller device, such as a personal digital assistant (PDA).

Cross-sectional construction details for reducing false signalling in the laptop touch tablet 2701 are shown in Figure 28. A laptop computer has several sources of internal noise, including a processor fan and internal loudspeakers. An insulating felt layer 2801 acoustically isolates the tablet 2701 from the chassis 2802 of the computer 2700. The underside of the

tablet area may be acoustically insulated using acoustic wadding. The internal loudspeakers are located in the base of the display portion of the case, to reduce interference when sounds are emitted.

In another alternative embodiment, the transmission of microphone signals from the touch tablet to the computer 101 is performed over a radio link, as indicated in Figure 29. Circuitry for the radio touch tablet 2901 is detailed in Figure 30. Analogue to digital converters (A-D) 2902 supply digitised microphone signals to a Bluetooth RTM baseband and radio frequency circuit 2903. The stream of digital audio from the A-D converters 2902 is compressed by a digital signal processor (DSP) in the Bluetooth RTM circuit 2903. The compression is a process of near instantaneous compression (NICAM), and is necessary in order to meet the relatively low bandwidth requirements of a Bluetooth radio channel.

Radio signals are transmitted via an antenna 2904. A rechargeable power source 2905 includes a NiMH cell, regulator and charging circuitry, which is connected to an external charger through a charging socket 2906. The rechargeable power source 2905 also includes a visual indicator (LED) on the side of the tablet, to indicate charging status during use, and during recharging. The microphones 2907 and 2908 used in the radio touch tablet 2901 are the same as those described in the preferred embodiment. Provision of the Bluetooth RTM radio link enables the tablet 2901 to be used with diverse processing systems, including mobile phones, personal digital

assistants (PDAs) and laptop computers. The radio link has extremely low power consumption, with most of the power for the radio tablet being consumed by the analogue to digital converter 2902.

In PCT/GB00/04635, by the present applicant, symmetrical microphone positions are used to obtain the location of a touch event upon the surface of a fully enclosed sphere. Distance from the sound source to a microphone is identified with reference to an attenuation model for sound propagation. The method described uses the acoustical properties of a spherical surface in which reflections do not occur. Templates are used, but the simplicity of the attenuation model requires only four templates, making the disclosed method several orders of magnitude simpler than is required by a reflection model. A spherical sensor of this type is difficult to manufacture, and the attenuation model would not provide the level of resolution required for a pointing device, or the precise navigation of 3D space, which is another of the uses of a spherical sensor of this type.

An improved spherical sensor is illustrated in Figure 31. The sensor 3101 rests in the one hand and is operated by a finger of the other hand. The sensor 3101 can be freely rotated and manipulated. The sensor 3101 transmits touch and orientation information over a radio link.

A hemisphere is shown in plan view in Figure 32. The hemisphere 3200 contains two microphones 3201 and 3202 that are located asymmetrically under its surface. Acoustic reflections from a flanged lip

3203 of the hemisphere ensure asymmetrical acoustic properties for the microphones when they are considered together. This can be achieved by electrically combining signals at their output, or by performing template analysis separately for each microphone signal. Each channel generates two possible locations, and these are resolved by combination. As a further alternative, full acoustic asymmetry for each individual microphone can be achieved by constructing the hemisphere of an irregular varying thickness of material. As yet another possibility, many microphones can be combined electrically in several combinations, resulting in two channels of differently mixed microphone signals. This achieves a rich complexity of acoustic systems unique to each possible location of the sound source on the surface of the hemisphere 3200.

In Figure 33, two such hemispheres 3200 and 3300 are connected together to form the sphere 3101 shown in Figure 31. Although physically connected, they remain acoustically independent, with the required reflection processes occurring from the flanged edge 3201 of each hemisphere 3200 3300 where the two hemispheres meet at the equator of the ball. Such construction provides the acoustic qualities of a reflection model, suitable for high precision touch event location. Replacement of components, such as a rechargeable battery, can be performed by simply unscrewing the two halves.

Combining multiple microphones into a single channel is illustrated in

Figure 34. A hemispherical or flat circular sensor 3401 has six piezo-electric microphones 3411, 3412, 3413, 3421, 3422 and 3423. Three microphones 3411 to 3413 are combined for a first channel, connected to the left channel of the stereo input to the computer sound card. The remaining three microphones 3421 to 3423 are combined for a second channel, for the right input of the sound card. The circuit of the sensor 3401 is shown in Figure 35. Each channel has three microphones connected in parallel. In this arrangement, constructive and destructive interference occurs physically and electrically.

In the sensor circuit shown in Figure 35, constructive and destructive interference occurs in the electrical domain as a result of electrically mixing the signals from transducer means at several locations on the surface. This electrical interference is therefore considered as part of the transmission system, when a circuit of this type is provided, and may be seen as an extension of the complexity of the transmission domain into a different medium. Such mixing may also be performed after microphone signals have been digitised, resulting in constructive and destructive interference in the time domain of digital samples. In a further possible configuration, time domain signals may be transformed into another domain, for example by the fast fourier transform, and the transformed results combined to form a single channel upon which analysis is then performed.

Claims

1. Apparatus for inputting data into a processing system, comprising a fricative surface for receiving user finger movements made against that surface, and transducer means arranged to receive sounds arising from the movement of a user's fingertip across said fricative surface; wherein:

said surface has a direct path and at least one reflection path for acoustic conduction of surface sound to said transducer means; such that interference between said paths occuring at said transducer means results in interference artefacts that characterise the location of said fingertip on said surface.

2. Apparatus according to claim 1, wherein said transducer means is located asymettrically with respect to acoustic properties of said surface.

3. Apparatus according to claim 1 or 2, wherein said transducer means is a contacting transducer means preferentially responsive to sound transmitted through the medium of said surface.

4. Apparatus according to any of claims 1 to 3, wherein said

surface includes acoustic transmission modifying means.

5. Apparatus according to any of claims 1 to 4, having two said transducer means, and further including connecting means for supplying signals from said transducer pair to an input of a processing system.

6. Apparatus according to any of claims 1 to 5, wherein a plurality of said transducer means at different locations have outputs that are electrically combined.

7. Apparatus according to any of claims 1 to 6, including digital radio transmitting means for transmitting signals from said transducer means to a processing means for identifying a location of said surface sound.

8. Apparatus according to any of claims 1 to 7, wherein said surface is curved.

9. Apparatus according to claim 8, wherein said curved surface forms a matching portion with another such apparatus, such that the combination of a plurality of such apparatus is a fully enclosed curved surface.

10. Apparatus according to any of claims 1 to 8, wherein said surface is part of a portable processing system.

11. A method of inputting data into a processing system, in which signals relating to user input movements on a surface are analysed to generate input data for said processing system; wherein

said signals are generated by transducer means in response to sound arising from a user input gesture being made upon said surface;

said surface sound is transmitted to said transducer means by a system of acoustic transmission paths, including a direct path and at least one reflection path; and

the location of the sound on the surface is identified by processing a characteristic of said path system with characteristics of other path systems of known surface location.

12. A method according to claim 11, including supplying signals from a pair of said transducer means to said processing system.

13. A method according to claim 11 or 12, wherein signals from a plurality of said transducer means are analysed independently to identify respective preliminary sound source locations.

14. A method according to any of claims 11 to 13, wherein said paths are modified by acoustic transmission modifying means in said surface.

15. A method according to any of claims 11 to 14, including transforming samples of said transducer signals into location characterising data.

16. A method according to any of claims 11 to 15, including electrically combining signals from a plurality of transducers.

17. A method according to any of claims 11 to 16, including transmitting digital representations of signals from said transducer means to a processing means over a radio link.

18. A method according to any of claims 11 to 16, including supplying said transducer signals to processing means in a portable processing system of which said surface is a part.

19. A method of processing a signal to determine a location of a sound source on a surface, wherein said signal has a characteristic that is determined by acoustic reflections in said surface, comprising the steps of:

characterising said location by transforming said signal to produce transformed data that reveals reflection artefacts; and

identifying a location for said sound source by processing said transformed data with a reflection model for said surface.

20. A method according to claim 19, wherein said reflection model is a set of templates.

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Claims searched: All

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

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Other: Online WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	DE 003027923 A1 (SIEMENS AG) see abstract, figs 1 & 2, page 5 lines 14 - 25 and page 7 lines 14 - 28.	1 - 4, 6, 8 - 11, 13 - 16, 18 - 18

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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